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ABSTRACT

While it is certainly too early to make a definitive assessment of the effectiveness of *Intelligent Transportation Systems* (ITS), it is not to take stock of what has been achieved and to think about what could be achieved in the near future. In our opinion, ITS developments have been up to now largely hardware-driven and have led to the introduction of many sophisticated technologies in the transportation arena, but the development of the *software component*, models and decision-support systems in particular, of ITS has been dramatically lagging behind. To reach the full potential of ITS, one must thus address the challenge of making the most *intelligent* usage possible of the hardware that is being deployed and the huge wealth of data it provides. We believe that transportation planning and management disciplines, *Operations Research* in particular, have a key role to play with respect to this challenge. The paper starts with a general presentation of ITS history, components, and architectures. It then focuses on two major aspects of ITS, Advanced Traveller Information Systems (ATIS) and Commercial Vehicle Operations (CVO) and Advanced Fleet Management Systems (AFMS), to review main issues, technological challenges, and achievements, and to illustrate how the introduction of better decision-support software, based on Operations Research models and methods, could very significantly improve the ultimate performance of ITS.

Keywords: intelligent transportation systems, architecture, ATIS, CVO, AFMS

RÉSUMÉ

Même s'il est certainement trop tôt pour évaluer définitivement les *Systèmes de transport intelligents* (STI), ce ne l'est pas pour faire le point et examiner l'avenir. Il nous apparaît, en effet, que les développements des STI ont été largement dominés par les considérations de *matériel* et donc, même s'ils ont permis l'introduction de nombreuses technologies de pointe dans le domaine des transports, la composante *logiciel*, modèles et systèmes d'aide à la décision en particulier, n'a pas suivi au même rythme. Afin de réaliser le plein potentiel des STI, il est donc essentiel à notre avis de pleinement relever le défi de la plus *intelligente* utilisation possible du matériel déployé et de l'énorme quantité d'information qu'il génère. Nous croyons que la *recherche opérationnelle* et les méthodes avancées de planification et gestion des transports doivent assumer un rôle de premier plan dans ce contexte. L'article débute avec une présentation générale de l'historique, composantes et architectures STI. Deux composantes majeures des STI, les systèmes avancés d'information aux voyageurs, ainsi que les systèmes avancés de gestion de flotte et d'opération des véhicules commerciaux, constituent le sujet principal du reste de l'article. Dans chaque cas, nous résumons la problématique, ainsi que les principaux défis technologiques et réalisations et illustrons comment l'introduction de systèmes d'aide à la décision sophistiqués, basés sur des modèles et méthodes de recherche opérationnelle, peuvent améliorer de façon significative les performances des Systèmes de transport intelligents.

Mots clefs : systèmes de transport intelligents, architecture, systèmes avancés d'information aux voyageurs, systèmes avancés de gestion de flotte, opération des véhicules commerciaux

INTRODUCTION

The term *Intelligent Transportation Systems*, or *ITS*, is generally used to refer to tomorrow's technology, infrastructure, and services, as well as the planning, operation, and control methods to be used for the transportation of persons and freight. With *ITS*, however, tomorrow is already here.

The driving force for the development of Intelligent Transportation Systems (formerly known as Intelligent Vehicle Highway Systems or IVHS) has been the realisation that further infrastructure construction could no longer be the only answer to address the increase in transportation demand and the various problems that it inevitably creates. It was thus necessary to find other ways to significantly increase the capacity of transportation infrastructures. The obvious answer was to try to make these infrastructures more efficient by using and integrating the latest developments in various areas, infrastructure and vehicle technologies, electronics, telecommunication, computing hardware, positioning systems, etc., as well as advanced data processing and sophisticated planning and operation methods. Over the last 15 years or so, one has thus witnessed tremendous efforts aimed at creating and deploying a new generation of transportation systems that aim to control congestion, increase safety, increase mobility and enhance the productivity and effectiveness of private and public fleets. In the beginning, *ITS* research, development, and investment focused on urban automobile transportation and a totally public organisational structure and management. It has now evolved to include all types and levels of transportation, persons as well as freight, for which private industries offer a variety of extended, adapted and targeted services. Tremendous challenges and opportunities exist in the field of *ITS* for research, development, and business.

While it is certainly too early to make a definitive assessment of the effectiveness of ITS in general or in particular settings, it is not to take stock of what has been achieved and, more importantly, to think about what could be achieved in the near-future. In our opinion, ITS developments have been up to now largely hardware-driven and have led to the introduction of many sophisticated technologies in the transportation arena. We are thus now, among other things, in the position to collect enormous amount of data about the current state and the operations of transportation systems, and to transmit rapidly these data, in one form or another, to transportation authorities, carriers, and travellers.

Two critical questions remain though: are all of these data transformed into *useful information*? And, is this information *properly exploited*? The correct answer to both of these questions is clearly negative. The reason for this situation is that the development of the *software component* of ITS, models, decision-support systems, and so on, has been dramatically lagging behind that of its hardware component. In many cases, very detailed data are still processed and acted upon by human operators with very few decision-support tools, if at all. In a sense, we are now faced with a challenge similar to the one that led to the initial development of ITS, that is, to make the best, the most *intelligent* usage possible of all that wonderful hardware that is being deployed. We believe that transportation planning and management disciplines, and in particular Operations Research, have a key role to play with respect to this challenge. The purpose of this paper is thus to make a somewhat partial assessment of ITS achievements in a number of key domains and to show how the introduction of better decision-support software, based on

operations research models and methods, could very significantly improve the ultimate performance of ITS.

The paper is organized as follows. Section I is dedicated to a brief overview of ITS history and main components, while Section II presents some of the major efforts aimed at the development of national ITS architectures. Whenever possible, we compare and highlight the similarities and differences between the ISO, American, Canadian, European and Japanese system architectures. We believe this comparison sheds new light on this important ITS aspect. The paper then focuses on two major aspects of ITS: Advanced Traveller Information Systems in Sections III and Commercial Vehicle Operations and Advanced Fleet Management Systems in Section IV. In each case, we review main issues and development stages, identify technological challenges and achievements and, through descriptions of possible applications of Operations Research, illustrate how the introduction of better decision-support software, based on operations research models and methods, could very significantly improve the ultimate performance of ITS. We conclude in Section V.

I. INTELLIGENT TRANSPORTATION SYSTEMS

Intelligent Transportation Systems represent the convergence of many fields of expertise toward the aim of improving the transportation infrastructure safety and efficiency. World-wide efforts are being put into research, development, and implementation of ITS technologies. The objectives for ITS are common world-wide, but the relative importance given to them often varies geographically. Previously known as Intelligent Vehicle Highway Systems (IVHS), the field was renamed ITS to reflect its more global and multimodal approach:

> "*A broad range of diverse technologies, known collectively as intelligent transportation systems (ITS), holds the answer to many of our transportation problems. ITS is comprised of a number of technologies, including information processing, communications, control, and electronics.*" ITS America

> "*ITS use information, transport and communications technologies, in vehicles as well as within the infrastructure, to improve mobility while increasing transport safety, reducing traffic congestion, maximising comfort and reducing environmental impacts.*" ERTICO

The term "transport telematics" is also used in Europe to stress the cooperation of transport, telecommunications and data processing (informatics) within ITS. **The core of ITS is obtaining, processing, and distributing information for a better use of existing networks**.

It is important to note that ITS is inscribed within a continuum in transportation management. It is not a brand new concept suddenly emerging but rather a logical evolution drawing upon old and new technologies. What is new about ITS is the vision of a globally integrated framework realising a synergy between previously isolated systems. The ITS revolution is thus to be analysed as much at the system and political integration levels as the technological level. This integration is not a simple task, however, as it must be done over a large array of disparate entities covering three broad areas: technical, political, and geographical.

At the technical level, ITS brings together the fields of transportation planning, telecommunications, computing, vehicle and electronics manufacturing, and infrastructure construction. Until recently, all these fields have been working rather independently of each other, following very different schemes and cultures. Road infrastructure building and transportation planning, for instance, are mostly done at a governmental level while development in the other fields are generally the result of efforts by private firms. Electronic appliances have a very fast paced development cycle and are short lived while automobiles evolve much more slowly and have a long tradition of standards and stability. In many areas, the knowledge and technology already exist, but must be brought together in an orderly fashion. At the political level, many entities are involved in the development, deployment, and operation of ITS: government agencies at the national and local levels, highway operators, equipment manufacturers, system vendors and service operators. They must all collaborate to implement and run a system that is composed of a mixture of public and private goods and services. As if these were not enough of a problem, for ITS to be successful, a geographical integration must also be achieved at a regional and, in many cases, even international levels. An end user would not like to be forced to buy a different set of equipment for each city or county he intends to

travel. ITS is all about mobility, it is not meant to infringe it! The efforts aimed at the development of national architectures attempt to address these issues.

1.1 Historical Notes

World wide research, development and deployment efforts in ITS can be more or less divided into four periods:

- **The beginnings**: in the 1960s and 70s, the idea of route guidance was at the core of a rather limited number of research projects. In the late 1960s, a research group initiated the *ERGS* (*Electronic Route Guidance System*) project in the US. It was followed in the 1970s by similar projects in Japan (*CACS*: *Comprehensive Automobile Traffic Control System*) and Germany (*ALI*: *Autofahrer Leit und Informations System*). These projects all shared the idea of central processing systems and dedicated communication systems to provide route guidance. The expectations were high, but no practical applications resulted due to the lack of suitable communication infrastructure and sufficient processing power.
- **Independent projects**: from 1980 to the end of 1994, several research projects were conducted, supported by great advances in computer science and telecommunications. Most of the efforts were directed toward the automobile and congestion problems. In 1984 the *RACS* (*Road/Automobile Communication System*) project began in Japan and became *VICS* (*Vehicle Information Communication System*) in 1991. In Europe from mid 1986 to 1995, the European Motor Industry led the *PROMETHEUS* project (*Programme for European Traffic with Highest Efficiency and Unprecedented Safety*) under the *EUREKA* umbrella. Simultaneously, from 1988 to 1994, the European Community was working on the *DRIVE* I and II programmes (*Dedicated Road Infrastructure for Vehicle Safety in Europe*). Meanwhile in the US, *Mobility 2000*, an unofficial study team was organised in 1988, providing a new approach to the issue. Not only were individuals from the government, industries and universities brought together to pursue a common goal, but more importantly, they established the basis of a permanent program co-ordination organism for a national IVHS (Intelligent Vehicle Highway Society) strategy and implementation plan. Not only were individuals from the government, industries and universities brought together to pursue a common goal, but more importantly, they established the basis of a permanent program coordination organism for a national IVHS (Intelligent Vehicle Highway Society) strategy and implementation plan. It was followed in 1990 with the creation of IVHS America which became in 1991 the advisory agency of the DoT, mandated by the US Congress to coordinate the development and deployment of IVHS in the US. In the following years, similar organisms were created elsewhere in the worlds: Ertico in Europe (1991), Vertis in Japan (1994), ITS Canada (1997) in Canada, to name a few.
- **Toward integration**: In September 1994, IVHS America became ITS America, marking a shift in paradigm which was already perceivable world wide. From experience gathered with earlier projects, it became more and more evident that an integrated approach was necessary for ITS to be successful. This integration was to occur at two levels. On one level, attention moved from a car-centric approach to a multimodal approach, giving more room to other modes of transportation. On a second level, a multitude of locally-development technologies and initiatives had to be integrated and harmonised in order to avoid a proliferation of incompatible technologies for the end users. This proved more difficult than anticipated. Europe and especially Japan had gained an early lead in small

and medium scale deployments of ITS, but were faced with the challenge of unifying these over their respective territories. A pan-European solution proved to be especially difficult in view of the different cultures and languages. The idea of an ITS framework or system architecture defining standards and how to assemble the pieces of the puzzle was put forth.

- **Toward standardisation**: The definition of well-structured ITS architectures allowed the definition and adoption of ITS standards. Mostly prevalent since 1999, this ongoing standardisation process is occurring at many levels (software, hardware, data formats, interfaces and protocols) and constitutes a crucial foundation for the deployment of large scale implementation projects.

1.2 ITS Components

As the ITS acronym implies, many different systems are called upon for the realisation of an intelligent transport infrastructure. While they often have evolved as different and autonomous entities, they all share data and information at one point or another and should therefore be integrated and viewed within a global framework. Many of these systems have a long history and have already been deployed in several countries around the world. In the following, we briefly describe the main ITS components. Their integration within the ITS framework is covered in the next section on architectures.

Advanced Traffic Management Systems (ATMS)

ATMS aim at a reduction of urban or road congestion by using adaptive real-time management of vehicle flows. Data gathering devices such as induction loop detectors, cameras, lasers or optical image processors relay data to a central *Traffic Control Centre* (*TCC*) through a wire line (telephone line, optical fibre, etc.) or a wireless network (cellular telephone, radio), etc. At the traffic control centre, this data is transformed into information using data fusion techniques, automatic incident detection models, and short term prediction models. Software and hardware devices are used to display traffic status. Intervention systems are then used to influence and manage the vehicle flows through Variable Message Signs (VMS), controlled traffic signals, or traveller information systems.

Even though they were not called ITS at the time, traffic surveillance and signal control systems have been in place since many years. One new aspect is the redistribution of information toward service providers and end users. There is thus an evolution from a traditional traffic control centre to a *Traffic Information Centre* (TIC).

SCATS (*Sydney Coordinated Adaptive Traffic System*) for traffic light control is in use in more than 40 cities around the world and most of the deployed ITS projects in the United States are ATMS systems. Data gathering and communication frameworks are thus well established in many cities. However, the data analysis stage (prediction, simulation) is still in its infancy.

Mobile phones will certainly assume an important role, not only to send data from traffic information centres to end users, but also as data gathering devices to send feedback information from end users to traffic information centres. This is sometimes referred to as *car probe data*.

Advanced Traveller Information Systems (ATIS)

These systems provide travel information to assist travellers in making mode choices, travel time estimates, and route decisions. This information can be given before the journey or en-route, and can be intended for a whole community or tailored to the specific needs of an individual.

Telecommunication infrastructures are at the core of ATIS with a wide range of technologies being used to distribute information to travellers. Traffic radio and television bulletins have been implemented in nearly all major cities around the world, but have many shortcomings. More and more, they are complemented by newer technologies that can reach a more targeted audience and make the information available in a more timely fashion. Radio Data Systems - Traffic Message Channels (RDS-TMC) for instance are well developed and implemented across the core of Europe while in Japan, VICS advanced navigation systems are in operation since 1996 with cumulative sales of car navigation units exceeding 3 millions.

Traditionally, ATIS referred to travellers as drivers or public transport users and information was tailored for each transportation mode and user group: car drivers, bus or subway riders, and so on. It must be noted, however, that the technology these systems use and the information they provide can be of great help in other contexts as well. Commercial fleet dispatchers for instance can use ATIS for a more efficient deployment of their vehicles, and freight carriers can make better decisions for the routing of vehicles and goods in a transportation network. Moreover, increasingly, information is targeted at the "multi-modal" traveller; the one that desires integrated guidance from the origin of its trip to its destination, irrespective of the transportation modes and transfer facilities used. The term "traveller" must thus be taken in a broader sense than just drivers or commuters, to include commercial fleets for example, and guidance must be understood in its most integrated form possible.

The great majority of the implemented ATIS systems use a travel guidance based on present conditions, not on short-term predictions. We will cover ATIS in greater details in a subsequent section.

Advanced Vehicle Control Systems (AVCS)

These are in-vehicle systems to assist the driver in adverse or dangerous conditions by implementing active safety measures such as vision enhancement, collision avoidance, lane keeping or speed control. Technologies such as on-board computers, sensors or video cameras, radar and laser detection devices, or guiding devices in the pavement are used to implement active safety measures to prevent accidents as opposed to passive safety measures coming into action after an accident has occurred (safety belts, air bags, crash-proved bumpers, etc.).

Car manufacturers mainly drive research and development in this area. Electronics to control vehicles are said to have gone through three generations: open-loop control at component level (engine ignition), close-loop control at subsystem level (ABS), and system integration level (cruise control). A fourth generation called by ITS might address the integration of the vehicle and the roadway. One of the first systems that should become widely available soon is the adaptive cruise control where the car speed is reduced upon detecting a lead vehicle then resumed to the initially-set speed when the lead vehicle changes lane. Models from Mitsubishi and Toyota are available in Japan since 1995 and 1997, respectively.

Some of these technologies are already available for luxury cars but are still a few years away from general availability as was the case with inflatable bags and ABS for example, which can now be found in every new car.

Commercial Vehicle Operations (CVO)

CVO systems aim at simplifying and automating freight and fleet management operations by implementing weigh-in-motion, commercial vehicle pre-clearance, vehicle and cargo identification and tracking, and international border crossing. These systems rely mainly on three group of technologies: vehicle or cargo positioning systems (GPS or radio frequency network), bi-directional communications with the vehicle driver (DSRC, radio or satellite), and Electronic Data Interchange (EDI) standard protocols. They are deployed at a regional, national or continental level.

The United-States have put a lot of effort in the implementation and deployment of CVO systems. The NorPass and PrePass systems are in use since the mid-1990s. These two (competing) systems cover most of the United States and extend in some parts of Canada. In Europe, the COREM project improves the transition between ship and truck transport modes by using innovative procedures for co-operative resource management. Five pilot projects are implemented in Germany and Greece.

CVO development efforts has been government-initiated and supported even when private industry is deploying and managing the systems. After initial hesitations, more and more carriers enrol in one or several projects. We cover CVO in some depth in Section IV.

Advanced Fleet Management Systems (AFMS)

Often linked to CVO systems in ITS presentations, and using the same technologies, AFMS are focused on the operations of a particular firm or group of firms. The emphasis is toward planning, scheduling, and monitoring a fleet of public or private commercial vehicles.

In the AFMS context, monitoring is not limited to vehicle tracking, but can encompass a detailed and continuous evaluation of the vehicle status (engine, brakes, fuel consumption, etc.) or of its cargo (temperature of sensitive goods, etc.). Moreover, in the case of freight transiting through different transportation modes (trucks, trains, ships, etc.), tracking and monitoring will be done at the level of the cargo itself rather than for a vehicle.

For efficient vehicle and cargo dispatching, scheduling, and routing AFMS is often closely integrated with ATIS. The real-time preoccupations, the uncertainties related to travel times and future demands, in particular, as well as the inherent complexity of fleet management and routing problems require sophisticated planning, management, and dispatching models and decision support systems. AFMS will be dealt with in more details in a Section IV.

Advanced Public Transportation Systems (APTS)

These systems allow a public transport operator to get real-time location, status and occupancy data from all the vehicle of its fleet. This data is then used to distribute information to travellers, perform incident management, give vehicle priority at controlled traffic signals or ensure passenger safety. APTS are mainly based on Automatic Vehicle Location and Control Systems (AVLC) technologies, but also borrow many technologies from ATIS and AFMS with

which they must be closely integrated.

A good integration example is in Gothenburg (Sweden) where users can get arrival times for all bus and tram stops in the city via their cell phones. Information can also be personalised. via a website where a user can order "surveillance" of one or more public transport routes. If there are any major delays on the specified routes, the telephone rings and a delay message is shown on the mobile telephone's display.

Electronic Toll Collection (ETC)

These systems are aimed at eliminating congestion induced by road tolls and allowing flexible fare structures that may vary with congestion or time related components. ETC systems are based on smart cards or transponders using Dedicated Short Range Communications (DSRC) to register the passing of a particular vehicle. Many different technologies are in use world wide, raising the problem of incompatibilities between deployed systems even some times within a single region. For the financing of road construction and maintenance, ETC systems are often the first type of ITS implemented in developing countries.

As ETC systems evolve toward the "full speed" payment model (vehicles do not slow down or go through a gate), more and more efforts must be put into enforcement measures. Technology and resources put into catching non-compliant drivers is thus becoming the limiting factor, not the payment process itself.

There is a trend toward an integrated electronic wallet allowing travellers to pay for the use of different facilities such as parking and transit fares with a single device.

Other Intelligent Systems

We briefly mention a number of other intelligent transportation systems:

- *Advanced Rural Transportation Systems* (ARTS). These are transportation systems adapted to areas with low population densities and long distance settings.
- *Advanced Parking Systems (APS).* These systems aim at eliminating the time spent searching for a free space and allowing reservation schemes. They are closely integrated with ATIS and ETC systems through the electronic wallet concept.
- *Automated Highway Systems* (AHS). These systems automate vehicle operation to reduce accidents and augment highway capacity. AHS is more and more associated to AVCS. It is funny to note that while AHS where in a way at the origin of ITS with ambitious goals in the 1960s, they are now considered the longest term ITS research projects. Major research projects are still under way, however. Prototypes exist and have been demonstrated in Japan and California and plans are for a deployment around 2010 in Japan.

II. *ITS SYSTEM ARCHITECTURES*

As stated earlier, integration is one of the main benefits of ITS but also constitutes one of its main challenges. One way to address the problem and bring together all the pieces of the puzzle is by envisioning and defining a master plan. Since several years, a lot of work and efforts have been put into establishing national or continental, pan-European, ITS system architectures.

An ITS architectures defines a stable reference to harmonize all ITS efforts within the area of interest and avoid duplication or incompatibilities. It must be emphasised that an architecture is not a design. It is rather a set of concepts, rules, and recipes to establish a stable framework within which several different designs could be implemented. It is thus a description of a class of solutions that will permit the creation of a number of designs, with different components. A major difficulty in defining a national ITS system architecture lies in establishing a good balance between precise definitions and openness to future technologies and needs. ITS systems are complex and encompass a large array of technologies, many of which are still in development or not existing at all. Thus, an ITS system architecture must be precise enough to serve as a stable reference for the development and co-ordinated deployment of present projects, yet it must not be closed to future technologies. It must accommodate for evolution and expansion and must also lead to systems that are both manageable and maintainable throughout their lifetime.

There are four major ITS architecture definition efforts: in the United States, Europe, Japan, and within an international ISO committee. The *American National ITS Architecture* is probably the most advanced and developed. The Americans have put an enormous amount of money and energy to define it prior to full scale deployment of ITS projects. The European architecture is less developed, but a fair amount of energy has been put into its definition. The European have more experience in ITS deployment than the Americans and this reflects in their architecture. At the other end, the Japanese only recently embarked in a formal definition of their ITS architecture. It is thus still sketchy. However, given the experience the Japanese have in ITS, their architecture is bound to have an important impact in the future. As for the ISO architecture, it is very similar to the American architecture and follows it closely. Canada has only recently defined its national ITS architecture. It is closely tied with the American architecture with some added Canadian specific features.

Given the complexity of a global ITS deployment plan, the corresponding system architecture will inevitably be a somewhat lengthy and complex piece in itself. In the following, we will give an overview of the concepts underlying ITS system architectures. Many concepts are shared by the major ITS system architecture plans. For implementation details, we will refer the reader to dedicated sources of information. Whenever possible, we will compare and highlight the similarities and differences between the ISO, American, Canadian, European, and Japanese system architectures. Other national efforts, Australia, China, France, and Korea, in particular, are underway and are briefly described in the last part of the section.

2.1 User Services and Requirements

The first step toward defining a complex system is to precisely identify the expected functionality. As seen by a user, what will the system offer, what will it do? The expected functionalities of an ITS architecture are defined as *user services*, also referred to as *user needs*. These services state in non-technical terms what an end user will obtain from the system and constitute a cornerstone for all subsequent development and deployment work. They form a sort of contract as to what will be delivered in the end product. They are also important as they often constitute the reference by which end users, government agencies, investors, and others will perceive and evaluate the envisioned ITS system. Hence, a lot of efforts and attention have been given to their formulation. The ISO Transport Information and Control System Architecture defines a standard nomenclature for 32 top level services in 8 areas.

The high level user needs are broken down into successively more detailed functional statements called *user service requirements*. Appendices A through D give an exhaustive list of user needs and user service requirements for the American, European, Japanese, and Canadian architectures, while Table 2 (at the end of the section) gives a side by side view of the user service level. It must be emphasised that this table does not lend itself to a direct comparison between the architectures. It is rather an entry point to allow comparison at the user service requirements level as given in appendices A through D. The top level user services are defined too broadly to allow a true comparison. The way they are interpreted and refined in user service requirements vary greatly from one architecture to the other. Moreover, to comply with the established standard, the European architecture has forced a fit of its user needs to those of the ISO TICS while defining more European-specific user service requirements. A global comparison at the level of the user needs thus leads to a false sense of uniformity. To establish a true comparison, one must "look under the hood" and see what is really defined at a lower level. Appendices A through D represent a lot of information, but are necessary if one wants to establish a sound comparison between the different ITS visions.

2.2 The American National ITS Architecture

As already noted, the Americans where among the first to identify and define a national ITS architecture. It was developed to support ITS implementations over a 20-year time period in urban, interurban, and rural environments across the country. The first version was completed in June 1996 and continuous efforts are put into improving and refining it. It is thoroughly documented in the Odetics website [Wnai].

The American ITS architecture is defined using a functional approach (as opposed to an object-oriented one) and closely follows the Hatley and Pirbhai (1987) methodology. At the top level, the American ITS architecture defines 31 services in 7 areas. They are further refined into more than a thousand user service requirements (see Appendix A).

At a second level, the *Logical Architecture* defines the entities evolving within and around the ITS system and how information flows between them to fulfil the identified user service requirements. The logical architecture defines three types of entities:

- *Terminators* representing sinks and sources for external information that flows to and from the Architecture;

- *Process Specifications* (P-Specs) describing in structured English the way in which they transform input information into desired outputs;
- *Stores* that are internal place holders for data.

The *Functional Specification* is expressed in two ways. First, in graphical form as *Data Flow Diagrams (DFD)*, and second, in more detailed textual form as *Process Specifications (P-Spec)* and data flow descriptions. Data Flow Diagrams are used to show the flow of data between the functional elements that make up the architecture. On a DFD, anything other than a store or data flow is shown as a circular object or bubble. A bubble may be a P-Spec or may further decompose into a lower level DFD. Terminators appear on the top level Context Diagram (which provides a precise definition of the ITS Architecture boundary) and on the top level DFD.

Each P-Spec is documented with its name, the inputs, the body (functional requirements), fulfilled user service requirements, and output. It also includes a measure of frequency for incident data flows. Each data flow (noted with an arrow in a DFD) is documented with its name, definition, description, and data sizing assumptions.

The *Physical Architecture* gives a physical (as opposed to functional) view of the ITS system. It must be noted that it is not a third level of abstraction subordinated to the Logical Architecture, but rather a different view onto the same system. It takes the processes (P-specs) identified in the Logical Architecture and assigns them to physical entities (called *subsystems*). In addition, the data flows (from the Logical Architecture) that originate from one subsystem and end at another are grouped together into (physical) architecture flows. One architecture flow may thus contain a number of more detailed data flows. These architecture flows and their communication requirements define the interfaces required between subsystems that form the basis for standardisation work.

The Physical Architecture is structured in 3 layers:

- The *Transportation* layer performs transportation functions such as traffic management and traveller information provision;
- The *Communication* layer represents the technology that will support the interfaces between transportation functions;
- The *Institutional* layer represents the policy makers, planners and other users of the ITS services.

At the transportation layer level, the functions defined in the architecture are contained within subsystems while the functions outside the scope of the architecture are represented by terminators. The Physical Architecture uses the same set of terminators as the Logical Architecture thus establishing the same system boundaries.

Figure 1, from the American National ITS Architecture, displays the 19 transportation subsystems (white rectangles) and the 4 general communication links (ovals) used to exchange information between subsystems. This figure represents the highest level view of the transportation and communication layers of the physical architecture. The architecture can be viewed at several more levels of detail below this first level. For example, consider the *Information Service Provider (ISP)* subsystem indicated in Figure 1. In an integrated ITS system, this subsystem plays a central role in the collection and distribution of transportation information. Its role is defined as follows in the American National ITS Architecture:

> "This subsystem collects, processes, stores, and disseminates transportation information to system operators and the traveling public. The subsystem can play several different roles in

an integrated ITS. In one role, the ISP provides a general data warehousing function, collecting information from transportation system operators and redistributing this information to other system operators in the region and other ISPs. In this information redistribution role, the ISP provides a bridge between the various transportation systems that produce the information and the other ISPs and their subscribers that use the information. The second role of an ISP is focused on delivery of traveler information to subscribers and the public at large. Information provided includes basic advisories, real time traffic condition and transit schedule information, yellow pages information, ridematching information, and parking information. The subsystem also provides the capability to provide specific directions to travelers by receiving origin and destination requests from travelers, generating route plans, and returning the calculated plans to the users. In addition to general route planning for travelers, the ISP also supports specialized route planning for vehicle fleets. In this third role, the ISP function may be dedicated to, or even embedded within, the dispatch system. Reservation services are also provided in advanced implementations. The information is provided to the traveler through the Personal Information Access Subsystem, Remote Traveler Support Subsystem, and various Vehicle Subsystems through available communications links. Both basic one-way (broadcast) and personalized two-way information provision is supported. The subsystem provides the capability for an informational infrastructure to connect providers and consumers, and gather that market information needed to assist in the planning of service improvements and in maintenance of operations."

The diagram for this subsystem (from the American National ITS Architecture) is given in Figure 2.

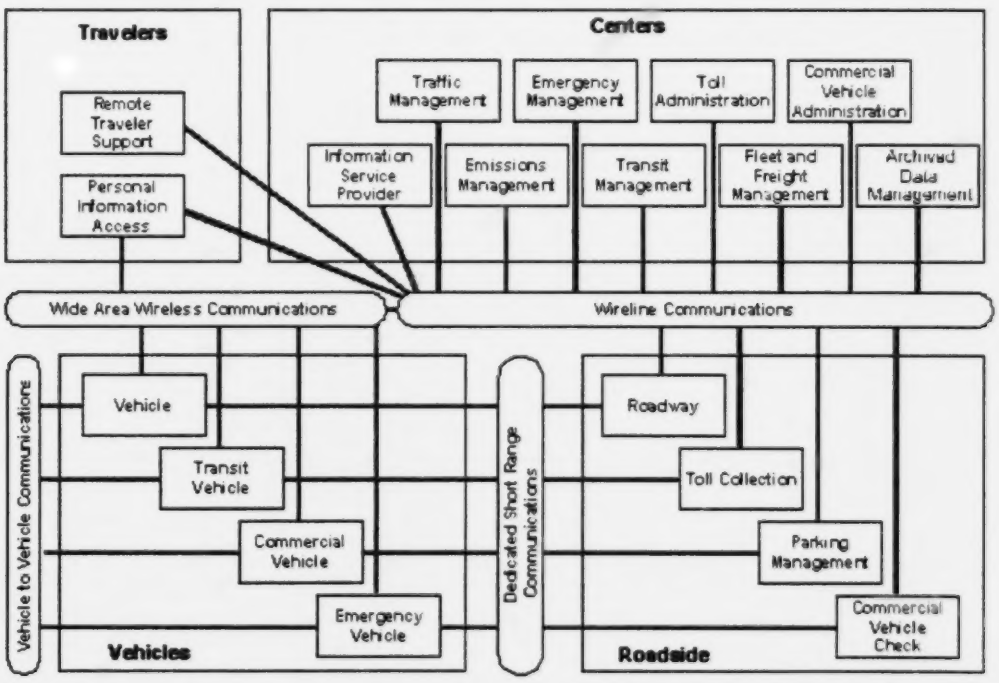

Figure 1. American Physical Architecture: Transportation and Communication Layers

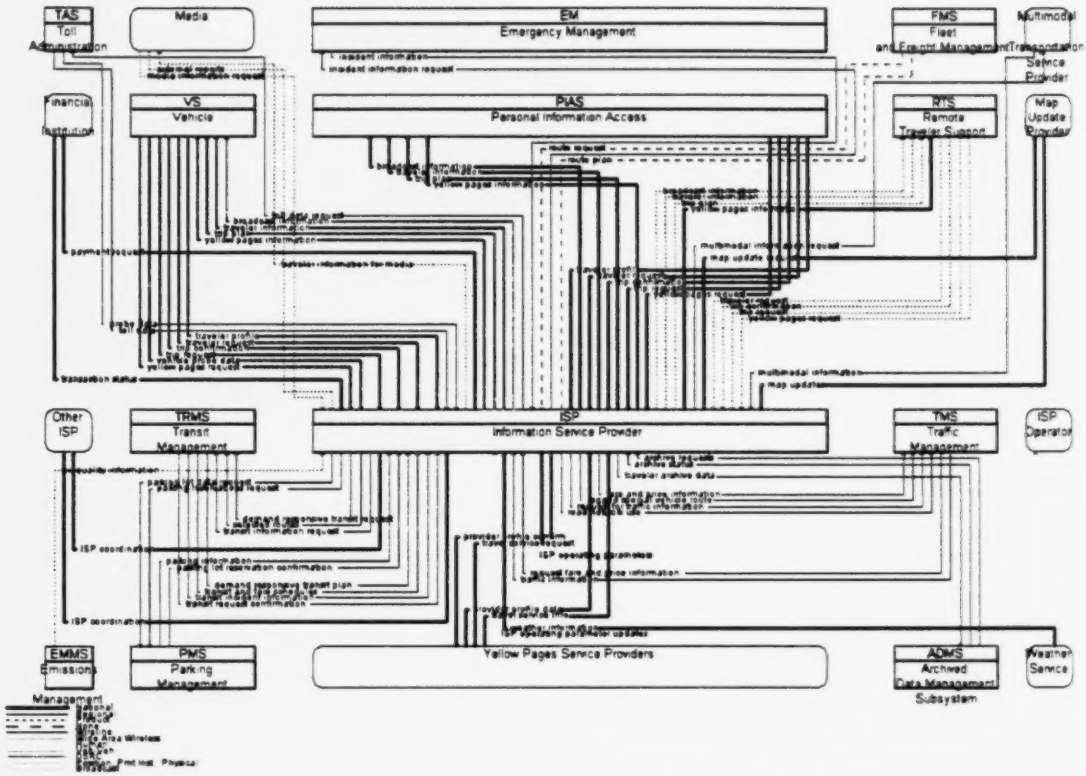

Figure 2. Information Service Provider Subsystem Diagram

While the ITS architecture is completely defined with the user service requirements and the logical and physical architectures, the American architecture introduces two other views to ease the evaluation and deployment processes:

- *Equipment Packages*:. These group like functions (P-specs) of a particular subsystem together into an "implementable" package of hardware and software capabilities. The architecture specifies the general capabilities of each of these functions and the interface of the function with other relevant functions. Around 110 such packages were defined.
- *Market Packages*: Each Market Package represents a service that could be deployed as an integrated capability. They are defined by sets of equipment packages required to work together (typically across different subsystems) to deliver a given transportation service and the major architecture flows between them and other important external systems. A total of 60 market packages were identified. Appendix E lists the definition of all market packages.

Equipment and market packages are certainly not prescriptive in nature and give one possible partitioning of the ITS system. Others can be envisioned and implemented.

2.3 ISO TICS Architecture

The ISO working group has taken the American architecture and rewritten it using an Object Oriented approach and the UML notation. As the American architecture served as a starting point for the ISO TICS architecture, the latter is being criticised as being too "American centric", not taking into account the specific needs of users in other parts of the world and therefore not suitable to establish a truly international standard. In addition, near the end of 1998, it is said that an international committee acknowledged the fact that the ISO TICS architecture was inconsistent in many respects in its lower layers and needed further refinements. The ISO effort thus seems to be galloping behind the European and American architectures instead of being the standard developing leader as it should.

2.4 The European Framework Architecture

In contrast with the Americans who have designed their ITS architecture with a *tabula rasa* approach, the Europeans are building their architecture framework upon the experience gained from many previous projects and "local" architectures. Even though the European framework is not yet finished, important projects such as *Tardis* in the Drive I programme, *Satin* and *Quartet* in the Drive II programme, *Converge* and *Quartex* in the T-Tap programme paved the way to a unified framework. Version 3 of the European user needs was officially sanctioned in June 1999 and the complete European Framework Architecture was presented in the beginning of 2000 as a direct result of the *Karen* project.

For reference purposes, European user needs have been organised following the ISO TICS Fundamental Services although it is agreed that such a classification is not satisfactory in terms of the European specificity (some ISO services have no counterparts in the European list). The European Framework defines 41 user needs in 10 groups. The list of user needs contains 510 entries, listed in Appendix B.

The Karen workgroup used the guidelines defined in the Converge project to establish a pan-European architecture. We will shortly describe here the concepts developed within the Converge projects.

In the European Framework, a lot of emphasis is put in obtaining not only a working system (one that will attain its goals) but also a workable system (one that will be easy to manage and maintain). Their system architecture therefore encompasses functions to attain both objectives. The Converge guidelines distinguish between three levels of architecture which together form a system architecture:

Level 3. *Multi-Authority - Inter-Operability properties*

> This level is necessary when the need for inter-operability between autonomous enterprises or authorities arises. It is similar in nature to level 2 but the issues to be considered are likely to be different.

Level 2. *Single Authority - System Properties*

> This level is necessary for the integration of functions and sub-functions in a working and workable manner. It is normally written as one or more Reference Models in which the main information and control flows are identified. If the ITS comes under a single authority then a Level 2 Architecture is probably the highest necessary.

Level 1. *Overall - System Structure*

This level defines the overall structure of the system, and how the sub-systems relate to each other. It describes *what* the various sub-units will do to attain global system goals. It will normally consist of at least four separate individual architectures:

- Functional Architecture - this describes the functions and sub-functions of the ITS, the flow of data between them, and the main databases;
- Information Architecture - this describes the data needed by the ITS, and their interrelationship;
- Physical Architecture - this describes the grouping of the functions into physical units, or even market packages, and the communication lines between them;
- Communication Architecture - this describes the flow of data between the physical units both in terms of message sets, and the characteristics needed of the media.

For some ITS it may also be useful, or even necessary, to include two additional architectures:

- Control Architecture - this describes the method of controlling of the system.
- Enterprise Architecture - this describes the commercial and/or business relationships of the various enterprises or authorities within the ITS. It will show the flow of resources between organisations, persons, services and/or functions.

Level 0. *System Design*

This is not an architecture level but rather a specific instance of an architecture. It describes *how* the sub-units are implemented.

One can see that level 1 more or less encompasses the same concepts of functional decomposition used in the American architecture structure. While such an approach is usually valid in a constraint-free environment, many organisational or behavioural issues are not considered because of the prime focus on functionality. Levels 2 and 3 were therefore added to address this issue and give a starting framework already taking into account external issues before engaging in the functional decomposition process. This multi-layered architecture is thus a tool allowing to take into account, among other things, legacy systems or national efforts before considering the solely functional aspect of the system. This is in contrast with the more monolithic approach taken in the American national architecture.

2.5 The Japanese ITS Architecture

Five government bodies related to ITS (Ministry of Construction, National Police Agency, Ministry of International Trade and Industry, Ministry of Transport, and Ministry of Posts and Telecommunications) are working on the development of the Japanese ITS System Architecture with the support of VERTIS, an organisation established jointly by the private sector and academic institutions. Documents pertaining to the Japanese ITS architecture can be obtained from the Vertis Web site [Wver] and in *The ITS Handbook in Japan* [Wmlit].

The Japanese were late in identifying the need for an ITS architecture and in defining one. Only the user services and the user service requirements were documented in early 1999. Version 1.0 of the completed architecture was presented in November 1999 at the Sixth ITS World Congress in Toronto.

The architecture defines 9 areas and 21 user services broken down into 56 specific user services and further refined into 177 specific subservices. The complete list is given in Appendix C. Compared to the American and European user service requirements, the Japanese list is sketchy and defined in very broad terms. It gives a good indication of the overall direction taken for the ITS efforts, but still needs to be refined and improved. While the American architecture is continuously updated and refined three to four times per year, the Japanese architecture is still at version 1.0 and has not evolved since its introduction in 1999.

2.6 Canadian ITS Architecture

Canada has only recently defined its national ITS architecture and issued version 1.0 in October 2000 [Witac]. Given the close relationships between United States and Canada and given also the degree of maturity of the American architecture, the best strategy for Canada is certainly to derive its national ITS architecture from the American architecture and make sure right from the beginning that both architectures are compatible. This is what was done by Transport Canada. The problem with the American architecture however is that it is very much U.S. centric and does not at all cover (nor does it attempt to cover) a pan-continental reality. In many areas, the political and cultural situation of Canada is more akin to Europe than to the United States. While a few attempts were made to incorporate some ideas from the European architecture, its multi-lingual and multi-cultural essence was not taken into account at all. We thus feel that an opportunity was missed here to benefit from both the American and European experience in ITS architecture design and anticipate some problems when the Canadian architecture will have to be adapted to provincial or regional contexts.

2.7 Other ITS Architecture Efforts

Beside the already mentioned ITS architectures, a few other countries are working toward defining national ITS architectures:

- Korea: A national project for setting up the Korean ITS national basic plan was initiated in August 1994 [Witsk]. It defines 19 service systems in 6 areas and layered into three types: basic, semi-basic/semi-additional and additional services. It also introduces the concept of a hierarchy of regions where ITS will be implemented.
- Australia: In May 1999, ITS Australia produced a report presenting their ITS Reference Architecture. A *reference architecture* defines the entities involved in a system and their inter-relation but at a more abstract level than a logical architecture. Using Object Oriented methodology and UML notation, the Australian Reference Architecture starts from the 32 ISO TICS Fundamental Services and closely follows the ISO TICS Architecture, but with adaptations for the Australian context. The Reference Architecture is defined, but no time frame is given for the logical and physical architecture definitions [Witsa].
- China: The country faces a different challenge as it must develop ITS simultaneously with the road infrastructure. While no official work has been published regarding a Chinese ITS Architecture yet, a joint declaration of cooperation was signed between ERTICO and the Chinese Transportation Systems Engineering Society in June 1997. This cooperation should give an early start for a Chinese ITS Architecture definition. A short report entitled *A Study on the Developmental Strategy of ITS in China* gives a good view of the overall

status in China [Witsc].

- France: A seminar was held in May 2001 to present the first results of the Actif project (Architecture Cadre pour les Transports Intelligents en France). This project builds on the Karen project to adapt the European architecture for France [Wact].

2.8 Conclusion

ITS architectures are not frozen concepts. They are still evolving and more work is necessary to refine them. However, they have attained a sufficient stability to fulfil their main goal as broad frameworks to guide a co-ordinated development and deployment of ITS projects. We believe no ITS project should be undertaken without due consideration in relation to a reference architecture.

In our opinion, the ISO TICS architecture lacks the strength and credibility needed for a true standard. It is too much just a reworked version of the American architecture. One would rather work directly with the American national ITS architecture which is much more developed, documented and accessible.

As for the Japanese ITS architecture, it is still under development and is not mature enough to be a useful tool at the moment. Given the importance of the Japanese work in the ITS field and their strong leader role in Asia however, their ITS architecture will certainly play an important role in the near future.

The American National ITS Architecture is certainly the most developed and mature framework. Combined with our geographical (and technological) proximity with the United States, these two points make a strong case in favour of our use of the American architecture. Moreover, it addresses the problem of longer term data sharing, a point not very well covered in other ITS architectures. On the other hand, the Europeans have a long experience of integrating ITS projects over many different countries. Their ITS architecture thus takes a multi-lingual and multi-cultural approach, an aspect totally lacking in the American ITS architecture. In that respect, the European ITS architecture is more adaptable to different contexts and closer to a true international standard. While pursuing a hybrid approach is probably not a viable solution (one follows a framework or does not), it is worthwhile to keep in mind certain features of the European architecture while working within the American framework.

A word of caution is necessary regarding ITS architectures. While it is absolutely necessary to devise and follow a global master plan for a successful ITS integration, it also fosters the danger of becoming a tunnel not allowing any side tracking or any potentially beneficial evolution (in the Darwinian sense of survival of the fittest). The Americans are already being criticised for "rushing" the standardisation processes now that they have defined their architecture. Standardisation processes have always been lengthy and incremental to make sure nothing was overlooked. Accelerating this process to the extreme could lead to flawed standards or, even worst, to standard solutions locking out better solutions. ITS architecture could thus be a two edged sword, but one must keep in mind that an architecture is a general framework allowing for the development of different designs. One should therefore follow the general guidelines of an ITS architecture but not necessarily feel bound to a particular implementation or technology.

TABLE 2. User Services in ITS Architectures

ISO 14813 32 services in 8 areas	USA 31 services in 7areas	Canada 35 services in 8 areas	Europe 41 services in 10 areas	Japan 21 services in 9 areas
	1. Travel and Traffic Management			
Traveller Information		1. Traveller Information	6. Travel Information	1. Navigation Systems
1 Pre-trip Information	1.1 Pre-Trip Travel Information	1.1 Traveller Information	6.1 Pre-trip Information	
4 Personal Information Services	1.5 Traveler Services Information	1.4 Traveller Services and Reservation	6.3 Personal Information Services	1.2 Destination Related Information Service 21: Information Utilization
5 Route Guidance and Navigation	1.3 Route Guidance	1.2 Route Guidance & Navigation	6.4 Route Guidance and Navigation	1.1 Route Guidance Traffic Information Service 21: Information Utilization
25 Shared Transport Management	1.4 Ride Matching and Reservation	1.3 Ride Matching and Reservation	10.3 Shared Transport Management	
2 On-trip Driver Information	1.2 En-Route Driver Information		6.2 On-trip Driver Information	
2 Traffic Management		2. Traffic Management Services	7. Traffic Management	4. Traffic Management
7 Traffic Control	1.6 Traffic Control	2.1 Traffic Control	7.1 Traffic Control	4.1 Optimization of Traffic Flow
8 Incident Management	1.7 Incident Management	2.2 Incident Management	7.2 Incident Management	4.2 Traffic Regulation Information in Case of Incident
9 Demand Management	1.8 Travel Demand Management	2.3 Travel Demand Management	7.3 Demand Management	
	1.9 Emissions Testing and Mitigation	2.4 Environmental Conditions Monitoring		
	1.10 Highway-Rail Intersection	2.8 Multi-modal Junction Safety and Control		
			2. Management Activities	5. Efficient Road Management
6 Transportation Planning Support			2.1 Transportation Planning Support	
11 Infrastructure Maintenance Management		2.5 Operations Management	2.2 Infrastructure Maintenance Management	5.1 Improve Maintenance Operations
10 Policing/Enforcing Traffic Regulations			3. Policing/Enforcing	
		2.6 Automated Dynamic Warning and Enforcement	3.1 Policing/Enforcing Traffic Regulations	
Vehicle	6. Advanced Vehicle Safety Systems	7. Vehicle Safety and Control Systems	8. In-Vehicle Systems	3. Assistance for Safe Driving
12 Vision Enhancement	6.4 Vision Enhancement for Crash Avoidance	7.3 Sensor-based Driving Safety Enhancement	8.1 Vision Enhancement	3.3 Assistance for Driving
14 Longitudinal Collision Avoidance	6.1 Longitudinal Collision Avoidance	7.1 Vehicle-based Collision Avoidance	8.3 Longitudinal Collision Avoidance	
15 Lateral Collision Avoidance	6.2 Lateral Collision Avoidance		8.4 Lateral Collision Avoidance	
32 Intelligent Junctions and Link	6.3 Intersection Collision Avoidance	7.2 Infrastructure-based Collision Avoidance	7.5 Intelligent Junctions and Links	
13 Automated Vehicle Operation	6.7 Automated Vehicle Operation	7.6 Automated Vehicle Operation	8.2 Automated Vehicle Operation	3.4 Automated Highway Systems
16 Safety Readiness	6.5 Safety Readiness	7.4 Safety Readiness	8.5 Safety Readiness	3.2 Danger Warning
17 Pre-crash Restraint Deployment	6.6 Pre-crash Restraint Deployment	7.5 Pre-collision Restraint Deployment	8.6 Pre-crash Restraint Deployment	
Freight and Fleet	4. Commercial Vehicle Operations	5. Commercial Vehicle Operation	9. Freight and Fleet Operations	7. Commercial Vehicle Operation
18 Commercial Vehicle Pre-clearance	4.1 Commercial Vehicle Electronic Clearance	5.1 Commercial Vehicle Electronic Clearance	9.1 Commercial Vehicle Pre-clearance	
19 Commercial Vehicle Administrative Processes	4.4 Commercial Vehicle Administrative Processes	5.4 Commercial Vehicle Administrative Processes	9.2 Commercial Vehicle Administrative Processes	7.1 Commercial Vehicle Operation Management

20 Automated Roadside Safety Inspection	4.2 Automated Roadside Safety Inspection	5.2 Automated Roadside Safety Inspection	9.3 Automated Roadside Safety Inspection	
21 Commercial Vehicle On-Board Safety Monitoring	4.3 On-Board Safety Monitoring	5.3 On-Board Safety Monitoring	9.4 Commercial Vehicle On-Board Safety Monitoring	
22 Commercial Vehicle Fleet Management	4.6 Commercial Fleet Management	5.6 Commercial Fleet Management	9.5 Commercial Fleet Management	7.1 Commercial Vehicle Operation Management
		5.5 Intermodal Freight Management		
				7.2 Automated Platooning of Commercial Vehicle
Public Transport	2. Public Transportation Management	3 Public Transport	10. Public Transport	6. Public Transport
23 Public Transport Management	2.1 Public Transportation Management	3.1 Public Transport Management	10.1 Public Transport Management	6.2 Public Transport Management
30 Public Travel Security	2.4 Public Travel Security	3.4 Public Travel Security	10.5 Public Travel Security	
24 Demand Responsive Public Transport	2.3 Personalized Public Transit	3.3 Demand Responsive Transit	10.2 Demand Responsive Public Transport	6.1 Public Transport Information Service 21: Information Utilization
3 On-trip Public Transport Information	2.2 En-Route Transit Information	3.2 En-Route Transit Information	10.4 On-trip Public Transport Information	
Emergency	5. Emergency Management	6. Emergency Management	5. Emergency Services	
26 Emergency Notification and Personal Security	5.1 Emergency Notification and Personal Security	6.1 Emergency Notification and Personal Security	5.1 Emergency Notification and Personal Security	
28 Hazardous Materials and Incident Notification	4.5 Hazardous Material Incident Response	6.2 Hazardeous Material Planning and Incident Response	5.3 Hazardous Materials and Incident Notification	5.2 Commercial Vehicle with Special Permissions
		6.3 Disaster Response and Management		5.3 Roadway Hazard Information
27 Emergency Vehicle Management	5.2 Emergency Vehicle Management	6.4 Emergency Vehicle Management	5.2 Emergency Vehicle Management	9. Emergency Vehicle Operation
				9.1 Automatic Emergency Notification
				9.2 Route Guidance
Electronic Payment	3. Electronic Payment	4. Electronic Payment	4. Financial Transactions	2. Electronic Toll Collection
29 Electronic Financial Transactions	3.1 Electronic Payment Services	4.1 Electronic Payment	4.1 Electronic Financial Transactions	2.1 Electronic Toll Collection
Safety				8. Pedestrians
31 Safety Enhancement for Vulnerable Road Users		2.7 Non-Vehicular Road User Safety	7.4 Safety Enhancement for Vulnerable Road Users	8.1 Route Guidance 8.2 Vehicle-Pedestrian Accident Avoidance
			1. General	
			1.1 Architectural Properties	
			1.2 Interoperability	
			1.3 Adaptability	
			1.4 Constraints	
			1.5 Continuity	
			1.6 CostBenefit	
			1.7 Expandability	
			1.8 Maintainability	
			1.9 Quality of Data Content	
	7. Information Management	8. Information Warehousing Services		
		8.1 Weather and Environmental Data Management		3.1 Road Conditions Information
	7.1 Archived Data Function	8.2 Archived Data Management		

III. ADVANCED TRAVELLER INFORMATION SYSTEMS

Traveling through a heavily congested network nowadays is akin to betting at a race track: based on experience and past statistics, one selects a runner and then do not have much decision power until the race outcome. In most cities, the information available before engaging in the journey is sparse and during the journey it is fragmentary if at all existent. Advanced Traveller Information Systems (ATIS) are designed to assist travellers in making mode choices, travel time estimates and route decisions. By being given high quality information about the network and its status, travellers are able to make better decisions and better use of the available infrastructure.

As noted earlier, one must keep in mind that the "travellers" benefiting from ATIS are not only car drivers or commuters, but can also be commercial fleet dispatchers or freight transportation decision makers for example. In fact, any vehicle moving through a complex transport system will be able to use it more efficiently with good and precise information on the present or predicted network conditions. ATIS encompass a large array of decision support systems. The information can be given before the journey or en-route, through fixed communication points or through mobile communication devices and can present actual or predicted network status.

3.1 Before Departure Information

Pre-trip information systems have existed since many years. Phone line information services and traffic information obtained by helicopter patrols and broadcast through radio or television bulletins have been available since many years. However, the cost of running an helicopter fleet, the limited accuracy and piecewise information thus obtained have considerably reduced its popularity. With the advent of Closed Circuit Television (CCTV) cameras installed in strategic locations, information could be made available on a continuous basis, and no longer subject to the randomness of checkpoint observations. These images were at first broadcast via special television traffic bulletins, and then via dedicated cable television channels. The growing tendency is to make these images also available via the Internet. Many cities around the world have dedicated Web sites where people can ask for images from specific sites. The service is no longer subject to radio or television schedules, is available on a twenty four hour basis and can even be tailored to ones needs. Several such live sites exist:

- With the *Compass* system in Ontario, camera views updated every three to five minutes are available for three major highways in the Toronto area. See the Compass section at the Ontario Ministry of Transportation Website [Womt].
- In Montreal, camera views from the highway monitoring system covering the major highways in the city and its suburb, as well as information on roadworks, can be obtained from the Quebec Ministry of Transportation Website [Wmtq].

- Numerous roadway report sites and real time network information for the entire United States can be accessed from a single Website [Wfhw].

While this represents a step forward, making an overall network status out of images from several cameras is cumbersome at best. The next step in the evolution is the gathering of data from several detection instruments and the presentation of the aggregated information on a Web site giving viewers the possibility to zoom into areas of interest. In the past few years, several such Web sites were put online and are quite successful:

- In Singapore, taxis send their position and average speed to satellites and are used as probes into the network. As taxis are especially active during peak periods, a relatively good network coverage is obtained for these crucial times [Wlta].
- Point-to-point real time traffic information and approximate travel time can be obtained for several U.S. cities [Wtra, Wmet].

Many other worldwide Traffic Cams and traffic report Web sites are listed in the transportation section of the Yahoo site [Wyah] and the traveller information section of ITS America [Wits]. The advantage of these Web sites is the continuous availability of the information and the fact that one can bookmark sections of these sites to jump directly to areas of interest, or use the personalization options offered by some of them. Some sites however suffer from their popularity and become difficult to connect to during peak hours, the periods when they are the most needed.

Another form of pre-trip information relates to maps and travel directions. A great number of CD-ROMS are available to view, search and print maps from a desktop or portable computer, easing the driver's task when traveling to remote or unfamiliar areas. Among the pioneers in that area, Tele Atlas [Wtel] in Europe and NavTech in the United States [Wnav] are now two of the main suppliers of geographic databases. Both have crossed the Atlantic and also expanded into Asia. Map services are also available via Internet where some Web sites freely give access to maps from all over the world. For example, the MapQuest Website [Wmap] can compute city-to-city directions all over America and door-to-door directions anywhere in the continental U.S. These informations can take the form of textual route-by-route directions or annotated maps and can be downloaded, printed, and even downloaded to a Personal Digital Assistant (PDA) for en-route viewing. Informations gathered in this maner are map based only and do not take congestion into account. There are few sites combining route directions and traffic data. One of the best known and best such sites is CitéFutée [Wcit] for the Île-de-France region in Paris. It computes the best itinerary between selected points, taking into account the observed real-time traffic flows. Precise travel indications are given, with distances and travel time estimates for each leg. Interestingly, a transit itinerary is also given, so one can compare both alternatives.

With a few exceptions, transit information systems are usually not as well developed. They often cover information about a single company or transportation authority. While they can be very useful to obtain schedules and when traveling through complex transit networks (mostly

trains and inter-city bus lines), the lack of multi-modal and regional integration often leaves the journey planning burden on the user side.

- The Montreal transit authority (STCUM) has a very good Web site tool allowing the specification of an origin, destination (either by clicking on a map or with textual information), and departure time to obtain two or three best route indications. It does take into account train, bus and subway schedules, but is unfortunately limited to the island of Montreal and does not cover adjoining regions [Wstc].
- Similar sites for Paris and Rome exist, but with textual input selection only. Multi-modal travel itineraries are covered for the Île-de-France region [Wrat] and Rome greater region [Wata].
- Subway itineraries for over 60 cities worldwide can be interactively computed along with travel time estimates [Wsub].
- In UK, the Railtrack Web site [Wrai] is said to have one of the highest hit rates of any Web page in the country.
- The European *INTERCEPT* project aims at delivering high quality multi-modal traveller information at a metropolitan level. It achieves a more global approach by the development of trip planner interconnection techniques (Hayes, Mentz, and Parker, 2000).

As can be seen, the Internet plays an important role in pre-trip traveller information systems. Web sites have evolved from a pure static form to an interactive exchange of information. This trend is likely to continue and even accentuate in the years to come. Web sites using Java for user interface and access to online databases are rapidly becoming a standard in this area. They provide a rich and easily navigable user interface and are readily available to any computer system equipped with an Internet connection and a browser. The drawback of these information sites however is that pertinent information gets fragmented over numerous sites. It can be a real challenge to first discover the sites of interest and then reassemble the information bits. The solution to this problem is the emergence of meta-Websites or portal sites giving a single point of access for information pertaining to a well defined domain. A traveller information portal would thus allow one to obtain and query integrated information about all transportation modes across a wide area. It is an ambitious project necessitating the cooperation of private and public agencies, but represents a huge opportunity for all participating stakeholders. In 1996, the American Department of Transportation launched the metropolitan area *Model Deployment Initiatives* (*MDI*) intended to demonstrate integrated transportation management systems and feature a strong, regional, multimodal traveller information services component. Four dense urban areas were selected as demonstration sites: Phoenix (Burdick, 1999), San Antonio (Chavers *et al.*, 1999), Seattle (West, 1999) and the New York, New Jersey and Connecticut greater area (iTravel Project Team, 1999). Each of these projects uses a Web portal to provide a single point of access for everything that travellers need to know to travel throughout the region:

- Phoenix: http://www.aztech.org
- San Antonio: http://www.transguide.dot.state.tx.us

- **Seattle:** http://www.smartrek.org
- **New York greater area:** http://www.itravel.org

The New York, New Jersey and Connecticut region, the largest transportation market in the USA, covers 29 counties spreading in these three states. The iTravel project will offer three separate traveller information services that will be implemented in stages:

- The first service is the Transit Itinerary Planning Systems (TRIPS). The complete transit schedules for public and private transit operators covering bus, train and subway routes for the 29 counties have been combined into a single massive interactive database. The information will be available through the iTravel Web site and will allow to create a customized travel plan based on personal travel preferences. It will include directions for access to the transit system, fare, payment options, and schedules, and also incorporate planned schedule changes and construction delays as well as real-time transit delays. A phone service will also be available for customers wishing to obtain additional informations.
- The second service called Traveller Information Center (TIC) will combine real-time traffic and transit information for the entire region. It will also be available through the iTravel Web site and telephone call-in system.
- While the first two services are free, the third service, Personalized Traveller Service (PTS), is a subscription-based service that will proactively notify individual travellers of real-time transportation information affecting their selected route and time of travel. PTS is event-driven, providing notification to an individual only when an incident or congestion occurs on the individual's registered route. Travellers may receive notifications through a variety of means such as email, fax, pager, cellphone, or other devices. This service will be offered for a monthly fee.

iTravel will be operated and maintained by the private sector, generating revenues from the paid services and advertising for the Web site and telephone system. It was intended to offer the TRIPS service in early 1999, but the project is behind schedule and iTravel presents a blank Web page for the moment.

The four MDI projects use the same approach: a set of free basic services financed through Web advertising and a value-added set of personalized services often offered for a monthly fee. The web sites for the other three projects are active and prove to be very successful. Another such site, Arizona TripUSA [Wari], was officially launched in June 1998 and features complete travel resources. Within the first two months over 50,000 page views and 6,000 individual visitors were counted. As for other Web-based ATIS, the problem is to overcome initial anonymity by many promotional activities such as submission to numerous search engines, press releases, sharing of links with highly visited sites and advertising in various tourist guides. The other major challenge is the achievement of a self-sustained Web site. Methods for capturing advertising and Web page development revenue sources is the key to ongoing operations and maintenance of the system (Cuevas Hansen, 1999). As these sites gain in popularity, more

independent service providers are approaching the Web maintainers to offer value-added and personalized traveller information services under the Web portal umbrella.

3.2 En-route Information

Travellers often lack a thorough knowledge of the transportation network (which, it must be admitted, can be quite complex) and tend not to use its full potential by restraining themselves to a few known routes. Good pre-trip information systems go a long way toward a better use of the available infrastructures. However, heavily used networks are dynamic by their very nature and congestion status can evolve or degenerate very rapidly. A travel time estimate obtained before undertaking a journey can have no bearing whatsoever with the reality once one is "in the field" a few minutes later. For this reason, updated information obtained while en-route has a higher value by offering the possibility to react in real-time and alter one's travel plan. This idea is not new and goes back to the early days of ITS research. However, only recently did technology catch up and truly allow wide distribution of information along this scheme. As for pre-trip travel information, radio broadcast was the early distribution media for periodic traffic bulletins. The problem with this media is the periodic nature of the broadcast: the bulletin following a missed one might well come in too late. Even though specialized channels can be used to broadcast continuous traffic bulletins, the problem of finding pertinent (local) information in the flow of data remains.

Across Europe, eleven countries have collaborated in the implementation of Radio Data System Traffic Message Channel (RDS-TMC) (ERTICO, 1999; McManus, 1998; European Commission Directorate General XIII, 1994). One of the key features of this technology is its ability to deliver information only pertaining to a driver's immediate route. The technology is now well deployed across Europe, especially in France, Germany and Sweden. The first concept of TMC came about in 1984, but little progress was made until the original European Commission DRIVE research and development program funded the first development of the ALERT-C protocol. The development of this standard TMC protocol was the key to the successful implementation of TMC across Europe. Data on traffic flows and weather is collected at centralized traffic information centers and is passed to the TMC traffic information service provider, which generates messages according to the ALERT-C protocol. These messages are then sent to radio stations that broadcast the silent RDS-TMC signals with their normal FM audio programming. In-car units translate incident and location codes into spoken warnings or screen messages. TMC messages can override, if necessary, on-going music and entertainment programs or even "wake up" the receiver to deliver the announcements. Because the codes have been standardized, the same message stream can be interpreted by the in-car unit into any language or format for the delivery to the driver. And since location codes are attached to each messages, they can be filtered so that only those relevant to the current journey are displayed. In the US, where it is called RDBS-TMC (adding a "B" for Broadcast), the technology is lagging behind. It is in use or planned to be used in a dozen major urban areas, but the lack of a national standard considerably hinders its deployment [Wrds]. A battle is raging between two competing standards (Sub-Carrier Traffic Information Channel (STIC) and Data Audio Radio Channel

(DARC)). Until some kind of settlement or marketing winner occurs, radio broadcasters and U.S. car manufacturers are adopting a wait-and-see attitude.

RDS-TMC however suffers from two main weaknesses: reliance on proprietary location databases matching codes to physical locations and its low communication speed of 37 bits per second (bit/s). It should be emphasized that this same speed problem plagues all data transmission technologies of en-route information systems. The desire to push more and more data through the communication channels stretch a given technology to its limit and rapidly calls upon a next speedier generation. Digital Audio Broadcast (DAB) coupled with the Transport Protocol Experts Group (TPEG) standard are seen by many as the successors of RDS-TMC [Wbbc, Wtpe, Wtti]. (In Canada, DAB is also known as Digital Radio Broadcast (DRB) while it is referred in USA as Digital Audio Radio (DAR) or DARS (for Satellite DAR) and as Digital Sound Broadcasting (DSB) by the International Telecommunication Union. Since the most preeminent standard emanates from Europe (Eureka 147 DAB), the DAB nomenclature is the most often used one.) It is much faster (from a basic data rate of 200 to 300 kbit/s up to 1.8 Mbit/s) and more easily upgradable as technology evolves. FM broadcasting was initially designed for stationary reception and when used for mobile reception, transmission quality can degrade a lot. Robustness to noise in mobile reception, high sound quality and efficient frequency utilization are some of the main features of DAB. But what makes it very attractive is its ability to concurrently transmit different types of data: audio, images, text and video can be combined and transmitted by the same carrier. TPEG is a protocol for traffic and travel information for use in the multimedia broadcasting environment (Gardiner, 1999; Wright, 1999). It can be used to send information by wire, digital broadcast or over the internet and can be extended to accommodate new devices and events. Unlike RDS-TMC, which requires an onboard database to interpret locations, TPEG can interpret new locations the moment they are first used without the need for any expensive cartographic surveys to update geographic data. It uses the same data sources as RDS-TMC and offers content and location filtering capabilities as RDS-TMC but at a much greater speed and with the possibility of message encryption for subscriber-only delivery. Furthermore, because it is built hierarchically, it allows a range of receiver types to be used simultaneously, ranging from sophisticated agent receivers serving navigation systems, through to simple receivers only able to decode top level information. The TPEG specifications have been submitted to CEN (Comité Européen de Normalisation) and are now in the process of being considered as a Work Item with a view to producing a European pre-standard. The TPEG protocol has been designed to be extensible. Initially, traffic and travel informations were considered with highest priority. The TPEG Working Group is now into the process of extending TPEG to public transport and status and travel time information (Marks, 2000). Canada has been among the early adopters of DAB and involved in research projects since the late 80's. Canadian broadcasters have set up DAB transmitters in Toronto, Montreal, Ottawa and Vancouver. These transmitters are able to reach 35 percent of the Canadian population. It is expected that this number will rise to 50 percent by the end of 2000, and to 75 percent by the middle of 2005. In UK, the BBC began an operational DAB service in September 1995 and they implemented a TPEG pilot service, with test transmissions on their national DAB multiplex and on the Internet, early in 1999. Except in the US where its adoption is slow, DAB has been implemented in many of the industrialized countries. DAB is thus a fast broadcast channel that is growing in popularity worldwide. It is however unidirectional. and one can only receive data. DAB technology alone is thus limited, but combined with other technologies such

as mobile telephony, it can become a key element in the offering of advanced information services. We shall come back to this point later on.

En-route transit information systems cannot rely on dedicated receivers reaching individual travellers. While it is possible to broadcast general information as done in the Montreal subway, it can not be tailored to each traveller's needs. Most of the time, travellers can access information kiosks in stations or selected sites. More and more, these are being replaced by information terminals giving schedule, route and tourist informations. In some instances, these terminals are directly connected to an Internet travel information portal such as, for instance, in the Arizona TripUSA project (Cone, Wootton, and Jeffreys, 1999). This could be termed as a *Checkpoint en-route information system* and does not necessarily give access to real-time transit information. For real-time and personalized transit information, the mobile telephone is the best medium. For instance in Gothenburg, Sweden's second largest city, users can get arrival time for all bus and tram stops in the city via their cell phones. This information is based on actual vehicle position and can thus be very accurate. Moreover, a user can personalize the information. Via a website, a user can order "surveillance" of one or more public transport routes. If there are any major delays on the specified routes, the telephone rings and a delay message is shown on the mobile telephone's display.

An important aspect of en-route information systems is the ability for a person or a vehicle to precisely determine its position. An accurate positioning system is essential in assessing a traveller's current situation and evaluating different route scenarios. One possible approach, known as dead reckoning, involves the use of transmitters evenly spaced along the routes to be travelled. These transmitters either send a specific signal to nearby vehicles, allowing them to know their positions, or they sense nearby vehicles, and send their identification to a central station. A few large scale systems are operational (see VICS below) or are in the prototyping stage (Cone, Wootton, and Jeffreys, 1999). However this approach has been mainly in use for relatively small networks like highway corridors, trains or bus lines, its extension to more extensive networks such as road networks being quite expensive and difficult to maintain. In recent years, satellite based Global Positioning System (GPS) has evolved very rapidly and opened endless possibilities in that domain. Although initially developed for military use by the US Department of Defense, its use for civilian purposes is widespread. While GPS allows a precision within thirty meters, signals destined for civilian usage are "scrambled" and accurate to about one hundred meters. The GPS satellites are owned and controlled by the US Department of Defense and this agency has the prerogative to degrade the accuracy for purposes of national defense. This is done by what is called "Selective Availability" or what is commonly known as "SA." SA is normally turned "on" but the DOD says that 95% of the time, position accuracy will be 100 meters or better. By combining the GPS position calculations with radio signals received from a GPS base station at a known location, many GPS receivers can compensate for the SA factor and improve the accuracy. This process known as Differential GPS (DGPS) corrects more than the errors intentionally added by SA and also corrects errors induced by satellite precision and the earth's atmosphere. Accuracy, which is limited primarily by receiver performance, then ranges from about ten meters to less than a meter. As technology evolved, GPS units got smaller and cheaper and can now be integrated into handheld devices.

In-car navigation equipments have closely followed the GPS development. While still at the gadget and luxury car equipment stage in Europe and North America, they have been in

widespread use in Japan since 1996 (Japan Ministry of Construction, 1999). It must be said that Japan has a very poor system of street signs, made even worse by a confusing method of assigning street addresses. In that context, a car navigation system is more into the realm of survival than it is elsewhere. The Japanese *Vehicle Information and Communication System* (*VICS*) started in april 1996. It uses infrared beacons, radio beacons installed along expressways and FM multiplex broadcasting to send information to in-car navigation units. Initially deployed in the Tokyo metropolitan area and along expressways up to about 100 km from Tokyo, the system now covers all of the country's expressways and its principal urban areas. Further expansion is being planned to cover the whole nation (Abe, Matsumoto, and Mishima, 1999). The system can provide real-time road traffic information using character, diagram or map based displays. As of July 1999, cumulative shipment of VICS receivers exceeded 1.2 millions units. One of the factors that contributed to the success of VICS is the early recognition by the Japanese government of the importance of digital maps and the efforts they have put into building a road network database in the late 1980s. With the advent of GPS and the fulgurant deployment success of mobile phones, several more advanced car navigation systems are now operational in Japan. These systems often use VICS receivers to gather information and mobile phone communication to add interactive and personalized services:

- *Intelligent Traffic Guidance System* (ITGS), launched in April 1997 by Daimler-Chrysler. The system can display the best route to reach a destination in the shortest time, after collecting real-time information on traffic congestion, restrictions, and accidents. The information is accessed and updated automatically at a specified interval (every 5 to 60 minutes). The system covers Tokyo and nine prefectures in the Kanto region and the surroundings, including Nagano. Text information about news, weather, parking availability, and flight status at Narita Airport is available nationwide.
- *MONET*, launched in November 1997 by Toyota. Besides "Live View" that displays real-time traffic congestion information using animated pictures, MONET has more than 40 items in the menu of services including e-mail communication, road traffic conditions nationwide, restaurants, tourist information, maps of 302 cities nationwide, news and weather. It can be used nationwide wherever portable phones can be used, and may also be voice operated while driving.
- *Inter-Navigation System*, launched in July 1998 by Honda. In this system, search functions using the internet to locate parking areas, police stations, hospitals, etc. are combined with a route guidance system. A private driving information homepage can be created by registering as a member in the dedicated web site via the internet. A personal database for driving routes can also be created as a part of the homepage using a personal computer. The database can the be accessed through a portable phone, a memory card or the car navigation system.
- *Compass Link*, launched in September 1998 by Compass Link Co. In this system, operators are available 24 hours a day to answer detailed requests from users, and to search for and send the requested information to the user's car navigation system to set a destination, display a map, establish a phone communication, etc. By contacting the operator, traffic information on the major roads in the Tokyo Metropolitan Area, today's news, and tourist information can be obtained. E-mails can also be received, fixed messages sent and hotel reservations made through the dedicated reservation center. In

addition, an "Auto-Compass Link" service is offered to registered users enabling them to select and access frequently-used information without operator intervention.

Cumulative shipment of car navigation units in Japan since 1992 reached 4.24 millions by the end of June 1999 and are now provided as an option for most new cars. There are now more built-in car navigation units than those installed afterwards, and it is becoming a standard automobile equipment. In USA, there are three relatively well established commercial traveller information providers, the Boston-based SmartRoute (*SmarTraveller*), the partnership of Metro Networks and Etak (*MERIT: Metro-Etak Real-Time Information for Travellers*) and CUE Corporation, a paging service that utilizes its nationwide FM subcarrier network to deliver information to drivers over car radios. All three companies focus on providing real-time traffic information (Orski, 1999). While at the forefront of car navigation technology, Japan faces the problem of proliferation of incompatible systems based on proprietary solutions. The problem can also be seen worldwide where many car computer systems, mostly developed by car manufacturers try to establish some standards. Of these, two technologies emerge as possible contenders for a wider standard: the Auto PC and AMI-C initiatives.

- The Auto PC is based on an Intel architecture and the Microsoft Windows CE operating system [Wapc]. Among its principal proponents are Microsoft, Intel, Clarion [Waut], Alpine Japan, Nissan, Citroen and Volkswagen. Some systems already exist, notably from Clarion, and Citroen recently announced the first Windows CE car.
- The Automotive Multimedia Interface - Collaboration [Wami] regroups nine automobile manufacturers (Daimler-Chrysler, Fiat, Ford, General Motors, Honda, Mitsubishi, Nissan, Renault and Toyota) aiming at defining a vendor and platform independent environment based on Java. The AMI-C interface is still in its design phase, but relies heavily on systems already implemented by Toyota and GM. As the name of the organization implies, these car manufacturers are "collaborating" and exchanging technologies toward a broader consensus and standardized platform. No doubt, the fear of a Wintel monopoly in the car manufacturing environment is a strong drive here.

Both approaches are quite different but aim at the same set of in-car multi-media services delivered via a wireless communication system. For advanced traveller information services, a low cost, efficient, and widespread two-way wireless communication system must be available. Mobile telephony satisfies these requirements of low cost, efficiency, and wide deployment, and is thus at the core of nearly all advanced information systems. Beside these qualities, three emerging technologies are aiming at promoting the mobile phone into an ubiquitous electronic device: EPOC, WAP and Bluetooth.

- EPOC [Wsym] is an operating system, application framework and application suite optimized for the needs of wireless information devices such as smartphones and communicators, and for handheld, battery-powered, computers. By offering a standard platform, a Java virtual machine, and integrated services such as messaging, browsing, office and utility applications, EPOC allows the development of new software that is readily

portable across a wide range of wireless devices. EPOC is used by most of the leading enterprises in mobile telephony: Ericsson, Motorola, Nokia, Matsushita, Philips, and Psion.

- Wireless Application Protocol (WAP) [Wwap] is a vendor-neutral and network-independent open specification standard for providing wireless Internet access from handheld devices. The WAP Forum was initiated by Symbian, Ericsson, Matsushita, Motorola and Nokia and is now comprised of 200 members including manufacturers representing 90% of the worldwide handset market, carriers with over 100 million subscribers, leading infrastructure providers, PC software companies and other companies delivering solutions to the wireless industry. WAP is designed to work with most wireless networks and can be built on any operating system. It is designed as a layered protocol ranging from a low level transport layer bridging different wireless network technology to a high level application environment allowing remote services and Internet access such as E-mail, messaging services and W access. In France, Alcatel and Webraska Mobile Technologies, a provider of real-time traffic information, maps and navigation on WAP mobile phones demonstrated in February 2000 a new service that relies on positioning technology to display mobile phone users' location on a map, to provide information on facilities surrounding them and to guide them to their destination using directions and maps [Wweb].
- Bluetooth [Wblu] is an open specification for short-range wireless communications of data and voice. Bluetooth technology enables users to connect mobile computers, digital cellular phones, handheld devices, network access points and other mobile devices via wireless short-range radio links unimpeded by line-of-sight restrictions. It delivers opportunities for rapid *ad hoc* connections, and the possibility of automatic, unconscious, connections between devices without the need of cables. Beside enhancing mobility, bringing Bluetooth in the car environment could have the added benefit of saving equipment investment. It is well known that car technology evolves much less rapidly than electronic or telecommunication technologies. By keeping the communication functions within a mobile unit, one can easily upgrade it as technology and services evolve without modifying the in-car equipment.

Brought together, these three technologies put the mobile communication device at the center of the Electronic Information Society by linking separate worlds: Bluetooth links devices together, EPOC links applications together and WAP links to the Internet. While predictions of the complete fall of personal computers to the reign of portable devices may be extreme, it is certain that handheld devices combining PDA functionalities, positioning, wireless communication and Internet access will play a predominant role in the near future. Nokia motto "Here, Now, For you" successfully catches the important features of the advanced information services to come (Hakala, 1999):

- Here: receive information pertinent to your location;
- Now: receive timely information from "push services" as events occur;
- For you: receive personalized information tailored to your needs.

However, present mobile telephones suffer from two serious drawbacks if they are to be used as portable all-encompassing devices: small screen size and slow speed of transmission. Accessing the Internet through a very small screen is a fairly frustrating experience, especially when comparing to the quality of access obtained from a desktop or portable computer. Adding to this the difficulty of entering data through the telephone buttons and the slow data transmission speed, and the Internet experience clearly becomes painful. These factors have led to a lot of dissatisfaction toward WAP in Europe recently [Wnng]. One of the problem lies in the great expectations that WAP proponents have built around that technology alone, selling it as an ideal gateway to Internet when in fact it does not compare favorably to other means of Internet access. Given the present state of mobile communication infrastructure and telephones, "push services" sending tailored and timely information in small quantities are much more appropriate than an access from the phone to the Internet. The strength of mobile telephones lies in their ubiquity and portability. Not before good and reliable push services are made generally available will WAP be able to leverage its full potential. In the longer term, the development and spreading of Bluetooth technology enabling a mobile phone to transfer its data to nearby data input and display devices (such as keyboard and monitor) will provide a true Internet access. In the meantime, WAP alone cannot make this happen (Bechler and Schiller, 2000).

As for the transmission speed, current GSM technology slowly transmits at about 9.6 kbit/s. Future enhancements such as the High Speed Circuit Switch Data service (HSCSD) and General Packet Radio Service (GPRS) will provide data rates of up to 115.2 kbit/s, but both will take some time to attain a wide coverage. France Telecom intended to roll out GPRS to its Itineris mobile customers near the end of 2000. Even then, when compared to DAB's basic data transmission speed of 200 to 300 kbit/s, these still represent low transmission speeds. Since DAB is unidirectional, there is thus a clear advantage in combining it with a two-way communication system such as GSM. In Europe, the ERTICO Diamond project [Wdia] (Ruf and Bosch, 1999; Veschambre, Darriet, and Fernier, 2000) is oriented toward the integration of DAB and other technologies such as GSM and GPS to provide fast multi-media ITS information services. It is envisioned that a mobile phone (GSM) could be used to send user requests and interactions while a DAB receiver could be used for fast data downloading, freeing the telephone channel. The transmission speed of DAB is such that it could be used to download software updates to the DAB receiver or, even more interestingly in an ATIS setting, complete regional maps. This would overcome the map update problem posed to most present in-car navigation systems. In Canada, a research project started in September 1997 by the Communications Research Center has led, in March 1998, to a prototype dual mode ITS system in Ottawa (Voyer and Edmonson, 1999) [Wcrc]. Since then the system is evolving and maturing.

Having a good in-vehicle communication system allows one to not only receive information, but also send information. Vehicles circulating on a network could thus become probes, automatically sending up to date traffic information and data as they travel. This could prove to be an invaluable network measurement instrument for a central management authority. With enough participating vehicles, a good assessment on the status of a network can be obtained. We have already mentioned taxis being used as probes in Singapore, but they still represent only a fraction of the vehicles on the network. Given the number of mobile phones in circulation, they could become very good probing sources. While the network coverage would be excellent, this method however raises privacy concerns. Not many would be willing to continuously send their position (and especially speed) to a central Big Brother while they drive. Any probing

technology should therefore be accompanied with strong measures ensuring anonymity and privacy of the probes.

From 1992 to 1994, and 1996 to 1998, the European *PROMISE* research programme focused on personal mobile multimodal travel and traffic information services using the GSM standard for mobile communication (European Commission Directorate General XIII, 1994; Hakala, Ojala, and Valio, 1997; Randall et al., 1997). The project also aimed at establishing an open architecture for the provision of mobile traveller and traffic information services in Europe. The project thus wanted to assure manufacturers and service providers of an ability to bring affordable products to mass market by avoiding fragmentation and proprietary solutions in the technical and conceptual platforms. Advanced information services were developed and deployed in Helsinki, Gothenburg, Rotterdam, Edinburgh, Paris and Munich using handheld devices for the intermodal traveller. Aimed at Europe-wide deployment, multimodal information and personalized services have been developed for portable and in-car devices so that travellers can receive these services anywhere, at any time and in their own language. Using a simple user interface, services allowed easy access to travel and traffic information during the whole journey. In addition, commercial services using this concept where implemented. An extensive evaluation exercise was carried out to assess technical performance, user acceptance and financial and socio-economic issues (Ojala and Lumiaho, 1999). The study involved around 50 persons for each of the pilot areas over a 6 month period. The anywhere-anytime access to multimodal travel information and mobility planning was particularly appreciated by the users. Two technical limitations were identified by the study: the slow Internet connectivity through GSM and the long response times and poor flexibility of the legacy transport information systems and trip planners used as information sources. It is expected that technologies such as WAP, increase communication line through GPRS and better designed source information systems would overcome these problems. From a service provider point of view, two features were identified as indispensable:

- Efficiency (reliable information, quick response time, customer care);
- Simplicity (clear content, user friendly interface, ease of use, personalization).

Of particular interest were the conclusions drawn by the companies and agencies participating in the PROMISE project consortium. They concluded that many of the most difficult aspects associated with offering PROMISE type services were organisational in nature. In particular it was felt that parties wishing to offer services should focus on the following:

- The role of the public sector; it is clear from the PROMISE trials that the public sector has an important role to play in the development of traveller and traffic information.
- Operational objectives of the system; all parties must state their objectives for participation in projects up front.
- The travel data collection and fusion process; People will only pay for services that are based on content that is reliable and of the highest integrity.
- Quality of data; it is very difficult to measure the accuracy of information delivered to

people. Unless a content provider or service provider actually has people constantly using the public transport or road system they cannot be one hundred percent sure that the data supplied to end users is totally accurate.

- Geographic coverage; presently it is very difficult to offer national, let alone pan-European, PROMISE services as most European countries do not have the required data to support these services on a wide geographic basis.
- The business and contractual framework under which organisations will operate; a contractual framework is essential if different organisations, regardless of whether they are from the public or private sector, are to work together.
- Legal liability; this is a difficult subject area and none of the PROMISE partners were happy to accept any legal liability when offering PROMISE services.

Their overall conclusion was that the economic viability of such services seemed to be strengthening as the trials indicated that people were prepared to pay for PROMISE type services provided they offer them a tangible benefit, as potential user base for services was increasing, and as cost of automated service provision were decreasing in regard to human-operated services.

3.3 Technological Challenges

The American ITS architecture defines nine market packages related to ATIS. Of these, six delineate a staged approach to ATIS, layered from basic broadcast system to more intelligent and integrated route guidance systems. While these six market packages (numbered *atis1* to *atis6* in the American architecture) are defined independently of the underlying technology, we relate them here to some of the technologies that appear to be in their future path:

- *Broadcast Traveller Information*. Collected real-time informations pertaining to traffic conditions, advisories, general public transportation, toll and parking, incidents, air quality and weather are disseminated over a wide area. As shown earlier, the trend in this area is to evolve from present FM subcarrier broadcast to more sophisticated and value-added digital dissemination such as DAB.
- *Interactive Traveller Information*. Information can be tailored in response to a traveller request. It is undeniable that internet is playing and will play an important role in the delivering of these services. Integrated transportation Website portals will create strong attraction points, the same way search engine portals did for general informations. Moreover, as WAP based mobile devices get more widely available, these services will move from pre-trip information to en-route information. In addition, the combination of mobile phones and value-added services such as "push" services where tailored information is sent based on a submitted user profile, are increasingly getting popular.
- *Autonomous Route Guidance*. Based on static, stored information, portable or in-vehicle equipment enables route planning and detailed route guidance. No communication with the infrastructure is assumed or required. The development of detailed digital maps and affordable precise location determination devices (mostly GPS based) have led to much

development in this area. These systems are however presently facing two major problems: the proliferation of many proprietary incompatible systems and the need to carry on-board and frequently update a potentially large number of digital maps. The Auto PC and AMI-C initiatives are seeking to establish some automotive industry standards. However, given the diametrically opposed approach of each camp (proprietary versus non-proprietary) the future seems divided and uncertain. As for the map problem, DVD could allow to distribute a very large quantities of maps while permitting relatively easy regular updates. It is suggested by many that DAB broadcasting could be the best solution. DAB stations could continuously broadcast the most up to date local or regional maps, allowing a traveller to go to any region and download maps as they are needed without the burden of carrying everything on-board.

- *Dynamic Route Guidance*. These services allow advanced route planning and guidance responsive to current conditions. Autonomous route guidance user equipment is combined with a digital receiver capable of receiving real-time traffic, transit, and road condition information. Significant amount of data could need to be transferred to the in-vehicle system. Given the speed and cost of present mobile telephony communications, a GSM based solution is unlikely. Again, DAB or at least UMTS based telephony will be necessary.
- *ISP Based Route Guidance*. Advanced route planning and guidance functions are moved from the user device to the information service provider. This approach calls for two way data communications. It simplifies the user equipment requirements and, as information is also received from the vehicle, can provide the infrastructure better information on which to predict future traffic and appropriate control strategies to support basic route planning with minimal user equipment.
- *Integrated Transportation Management/Route Guidance*. This market package allows a traffic management center to continuously optimize the traffic control strategy based on near-real time information on intended routes for a proportion of the vehicles within their network while offering the user advanced route planning and guidance which is responsive to current conditions. It would utilize the individual and ISP route planning information to optimize signal timing while at the same time providing updated signal timing information to allow optimized route plans. This is a long term goal as both ATMS and ATIS are still in their early development and deployment stages.

While we have covered most of the technological aspects of ATIS implementations, we cannot close our survey without mentioning another important and challenging topic: the human-machine interface. Driving a car requires the integration of a lot of informations and stimuli from the immediate physical and visual surroundings by the human brain and thus necessitates the full concentration of the driver. One of the aim of ATIS is to bring to the driver informations from events and areas not immediately perceivable by him. This can potentially lead to an information overload for the driver and create dangerous situations. In Japan, studies have shown an increase in accidents due to in-vehicle guiding equipment distracting the driver from his main task. Similarly studies establish a correlation between accidents and the use of cellular phones while driving (Tokunaga, Hagiwara, and Onodera, 2000; Laberge-Nadeau *et al.*, 2001). The solution seems to lie in a technology that could deliver the ATIS information while keeping the hands and eyes for the driving task. A lot of efforts were thus put in the development of speech operated

devices, but recent studies (Lee *et al.*, 2000) tend to show that these still lead to a level of stimuli and distractions that represents a danger while driving. The European Commission has recently issued recommendations for the assessment of the safety and efficiency of in-vehicle information and communication systems (Stevens and Quimby, 2000). The problem is therefore a real challenge requiring the development of better interfaces and communication means to bring more informations while keeping the driving task safe.

3.4 The Role of Operations Research in ATIS

With the exception of the autonomous route guidance systems, all the systems mentioned in the previous section rely on the availability of real-time traveller data from roadway instrumentation, probe vehicles or other sources. As the infrastructure and the telecommunication means mature and get more widely deployed, phenomenal amount of data gets gathered. It is absolutely impossible (and useless) to redistribute this raw data to the end user. It must be processed and aggregated in a timely fashion to be of any value to a traveller. While a lot of research and development efforts have been put in the telecommunication and road infrastructure equipments, much less efforts have gone into data processing and algorithms. We could be getting to the point of being data rich, but information poor. To turn data into useful information and to properly exploit this information, one must develop the software component ("the real inteligence") of ATIS. It is at this juncture that transportation planning and management disciplines, and in particular Operations Research, have a key role to play.

The great majority of travellers information systems that are being developed and deployed rely on present network conditions. Situations can evolve and deteriorate very rapidly, especially in a dense urban environment where ATIS are the most needed. A route selected as the best one on present conditions can turn out to be the worst one when a traveller gets on the road. To be of greater value, route guidance should be based on predicted network conditions that will prevail at the time of intended traveling.

One of the main challenges when one wishes to use the predicted network status as the basis for route guidance is, quite obviously, the need to correctly forecast the state of the network at some later points in time. Ideally, one must be able to predict travel times on network links for a time horizon ranging from a few minutes to an hour or two (the "guidance horizon"). This task is further complicated by the fact that these travel times might evolve drastically (and sometimes, unpredictably) over the guidance horizon. One thus needs to forecast travel times at various instants (ideally, continuously) over the chosen horizon. Several approaches can considered for this purpose, but they all rely on fairly sophisticated techniques borrowed from statistics, operations research and computer science. These techniques can be broken down into three main groups: statistical approaches, traffic simulators, and methods based on dynamic traffic assignment models.

Statistical approaches are typically based on some form of time series analysis technique and usually work on a link per link basis. The underlying idea is to model the travel time for any

given link and instant through a statistical model that takes into account past and current travel times. Other independent variables such as the day of the week and weather conditions can also be integrated into the model provided that a suitable data base incorporating these elements has been collected and validated. In spite of their relative conceptual simplicity, these approaches are not easy to implement because of the huge data collection effort that they require. One can also seriously question their predictive capabilities, since they fail to account for network interactions and do not make use of the extensive information available on the current state of the network.

Traffic simulators are computer programs that aim at reproducing the evolution of traffic flows on a network through time. The basic idea is simply to simulate the movements of vehicles along their intended routes by applying a set of rules to govern these movements. Future travel times along links can be obtained by collecting statistics on the times incurred by vehicles as they are moved on the network; travel time predictions in the future are thus merely the result of *observing* the simulated network as it evolves through time. Traffic simulators can be broken down into three main classes: micro-, macro- and meso-simulators, that we will now briefly discuss.

Micro-simulators are probably the most commonly used traffic simulators at this time. Simulators such as *TRAF-NETSIM* (Yedlin *et al.*, 1994), sponsored by the Federal Highway Administration, *INTEGRATION* (Van Aerde, 1999), *AIMSUN2* (Ferrer and Barceló, 1993; Barceló *et al.*, 1995; Barceló *et al.*, 1998; Barceló, 2000), and *VISSIM* (Fellendorf, 1994) are distributed commercially and widely available. Micro-simulators were developed originaly to perform detailed traffic engineering analyses of small portions of networks (usually a single or a handful of intersections). Consequently, in these, the (sub-)network under study is described in great detail, the time step is quite small (usually, a few seconds), and vehicles are moved individually according to complex rules pertaining to car following (Gazis, 1974; Gabard, 1991) and lane changing (Gipps, 1986). Early micro-simulators directed vehicles on the network on the basis of observed or expected turning proportions at intersections, but more recent ones (see, for instance, Barceló *et al.*, 1995; Barceló, 2000) move vehicles on origin-destination paths; these paths can even be updated dynamically and revised during the simulation using a shortest path computation routine and a route choice model. These improvements greatly enhance the quality of results that one can expect from the simulations. An inevitable consequence of the high level of detail provided by micro-simulators is that their computational and data collection requirements are quite heavy, even for fairly small networks. These can become completely out-of-hand when larger traffic networks are considered. It follows that micro-simulators cannot be used to simulate large networks for route guidance purposes, because they cannot provide valid travel time predictions in real time. In spite of this limitation, advanced micro-simulators have been and continue to be developed for ATMS/ATIS purposes; for instance, AIMSUN2 was the simulation tool used in the *ENTERPRICE* European Project (ENTERPRICE, 1999). One reason for this is that there are many reasonably sized urban networks where most of the congestion occurs only on a relatively small sub-network that is tractable for a micro-simulator (one would expect this to be the case for many small or medium-size cities, in particular in Europe): by focusing on this critical sub-network, one can retain the advantages of a detailed simulation without incurring inordinate computation times. This idea can be extended to handle larger networks by coupling micro-simulators with more coarsely-grained simulators: under such a scheme, only the most critical portions of the network are again simulated at the microscopic

level, while the remainder is handled by the less demanding macro- or meso-simulator. In such a case, however, complex issues regarding the interactions between the two simulators need to be carefully addressed (see, for instance, Lerner *et al.*, 2000; Poschinger, Kates, and Meier, 2000).

Macro-simulators take a much more aggregate view of the traffic network. In these, the description of the network is much cruder and the time step is larger. These macro-simulators are commonly based on the analogy between traffic flows on a street or highway network and a fluid flowing in a network of pipes according to the laws of fluid dynamics (Lighthill and Whitham, 1955; Richards, 1956; Bick and Newell, 1960; Munjal and Pipes, 1971). Typically, traffic is described by considering the overall number of vehicles on a link (distinguished by destination) and classical flow/density relationships from traffic engineering (Greenshields, 1935) are used to determine how vehicles move over the network. Later models include more detailed descriptions of vehicular traffic (Payne, 1971; Philips, 1979; Kerner, Konhaüser, and Shike, 1996; Helbing, 1997; Reimers, 2000). In spite of these developments, the treatment of intersections, which are a critical element in real traffic networks, remains too simplistic to allow for a proper representation of their impact on flow dynamics and travel times. It thus follows that while macro-simulators may offer a tractable alternative from a computational standpoint for a route guidance system, their modeling accuracy is probably much too low to hope to derive truly satisfactory travel time estimates from them.

Meso-simulators have appeared in the last few years (Jayakrishnan, Mahmassani, and Hu, 1994; Nagel *et al.*, 1998; Ben-Akiva and Bierlaire, 1999). They represent an attempt to bridge the gap between micro- and macro-simulators by combining ideas borrowed from these two classes. The main objective is to try to develop modeling frameworks capable of handling large networks with a reasonable data collection and computational effort while retaining a high level of accuracy with respect to the description of traffic dynamics. While it is possible to provide a fairly unified description of micro- and macro-simulators, this is not longer true when dealing with meso-simulators: each simulator represents a unique attempt to blend effectively concepts from the two other classes, along with novel ideas. Some constants do, however, emerge. For instance, vehicles are usually represented individually or in small groups (packets). This is currently a very active research area and one can reasonably hope that, within a few years, meso-simulators capable of supporting real time route guidance in an ATIS context will finally become available.

Dynamic traffic assignment (DTA) models also aim at predicting the dynamic evolution of traffic flows over a street or highway network. Their perspective differs, however, quite significantly from that of traffic simulators. This stems from the fact that DTA models were originally derived as a temporal generalization of the static traffic assignment (STA) models that have now been used very effectively for transportation planning purposes for several decades (typical examples of early DTA models can be found in Friesz *et al.*, 1989; Janson, 1989; Wie, Friesz, and Tobin, 1990; Boyce, Ran, and LeBlanc, 1992; Drissi-Kaïtouni and Hameda-Benchekroun, 1992; Friesz *et al.*, 1993). Standard STA models are based on the principle of *traffic equilibrium* that states that, for any given origin-destination pair, all routes used by drivers (or by transit users in a transit assignment setting) have the same cost (travel time) and this cost is no larger than that of unused routes (see Florian and Hearn, 1995, for a detailed overview).

Traffic congestion is accounted for through *link-delay functions*. These functions simply state that the travel time on any given link increases with the number of drivers using it. It is the interplay of these flow-dependent travel times that leads to the equilibrium state postulated by the traffic equilibrium principle. In STA models, it is assumed that the planning period under consideration is homogeneous and that flows and travel times are constant over it. This is obviously a gross simplification. For almost twenty-five years, researchers have strenuously tried to overcome it by addressing the fact that traffic flows and travel times do evolve significantly during a peak period, for instance. In spite of all these efforts, no DTA model has yet emerged that achieves a significant consensus in the community. Apart from a series of technical problems that have been encountered (in particular, the difficulty of defining sets of equations accurately describing the complexity of traffic dynamics and interactions), this can be possibly traced back to a major conceptual inadequacy: the equilibrium modeling approach on which STA models are based attempts to capture some kind of steady-state, limiting behaviour that bears little relationship to the inherently transient nature of short-term traffic flows. Another important limitation of DTA models are the data requirements, which can be frightening when translated in a dynamic setting. In recent years, many DTA models have evolved in the direction of hybrid models incorporating many features from traffic simulators while retaining some of the basic analytical concepts of traffic equilibrium (see, for instance, Lo, 1999; Rubio-Ardanaz, Wu, and Florian, 2000; Autenrieth and Reimers, 2000; Er-Rafia, 2000; Mahut, 2001). In fact, the dividing line between this new generation of DTA models and meso-simulators tends to disappear over time and the distinction between these two classes of approaches may eventually become essentially academic. Another important development in the area of DTA models over the last decade is the explicit accounting for en-route guidance information in order to accurately represent the ATIS environment (see, for instance, Cascetta, Coppola, and Adamo, 2000, for an example of a state-of-the-art assignment model that captures the impact of ATIS on pre-trip choices).

The implementation of DTA models, as well as of the majority of the most recent and most sophisticated traffic simulators, relies heavily on Operations Research techniques. In particular, in order to assign drivers to suitable paths between their origin and their destination (and, in many cases, revise this assignment), shortest paths must be repeteadly computed. The most advanced implementations account for the variations of link traversal times over the guidance horizon, which implies that *time-dependent* shortest path problems must be solved. These problems are significantly more difficult than standard, static shortest path problems and to solve them efficiently, one must use appropriate techniques (see Pallottino and Scutellà, 1998, for a comprehensive and insightful survey of shortest paths algorithms in transportation models). Another critical issue is that of the estimation of origin-destination (O-D) flows (the traffic demand). These flows must, obviously, be estimated *a priori* to feed the models or the simulators with initial values for the number of travellers wishing to move between the various points on the network at different times. Several estimation techniques have been devised for this purpose (see Ben-Akiva and Bowman, 1998, for a description of the popular activity-based approach and further references) but, in an ATIS environment, one would also often want to revise these initial estimates on the basis of observed flows, a particularly difficult task. This difficulty is compounded in the case of micro-simulators by the fact that only part of the network is usually simulated and, consequently, one must estimate demands between "boundary" points of the sub-network being simulated that may change very rapidly on the basis of traffic conditions or of the

information provided to travellers (for instance, drivers may have to re-route to avoid accidents or stongly congested areas). Barceló and Casas (1999) (see, also, Barceló, 2000) describe a possible approach, based on neural networks, for tackling this problem, but much more work is probably required to address its various facets.

Another promising recent development with respect to the prediction of travel times in an ATIS context is the concept of "nowcasting". This concept refers to the idea of making full use of the powerful short-term weather prediction techniques that are currently available by integrating short-term weather forecasts as a key input for other forecasting or decision-support activities. For instance, rainstorms or snowstorms can now be accurately predicted over an horizon of a few hours. If these forecasts were made available to a route guidance modules, one could avoid sending travellers to areas that will be hard hit by such storms in the near future. A main challenge here is obviously the translation of weather information into usable traffic network information, but significant developments can be expected in this area in the coming years.

Many of the most advanced models and simulators described above have pretty significant computational requirements. If they were applied to large networks, several of these could easily require, on a reasonably powerful computer, running times much greater than the simulated time period. Apart from the improbable use of super-computers for ATIS purposes, the only viable alternative for providing real-time guidance is probably to resort to distributed processing. By distributing the workload on several computers handling the simulation and decision-support over smaller sub-networks, real-time response could be achieved, but this opens up several challenging questions regarding the overall consistency of the simulations and the global optimality (where relevant) of the guidance provided. In spite of the rapid pace of improvement in computer technology and performance, this is an area where more research is needed.

An important issue when dealing with advanced models for ATIS is taking the step from academic models and prototypes to deployed systems. From 1996 to the beginning of 1999, the European *CLEOPATRA* project (*City Laboratories Enabling Organisation of Particularly Advanced Telematics Research and Assessment*) was dedicated to the development and validation of methods and algorithms to support guidance and information systems [Wcle]. It developed techniques and algorithms for network state estimation and prediction, focusing on the following applications:

- Path Flow Estimation;
- Journey Time Prediction;
- Prediction of Incident Effects;
- Strategies for Individual and Collective Information and Guidance Systems;
- Strategies for Variable Message/Direction Sign systems;
- Strategies for In-Vehicle Information systems.

CLEOPATRA's main results are a series of software and products tested in several European cities, and made available to European industries active in the domain of information and dynamic guidance systems.

In Germany, a system for short-term forecasting is being developed. Called *MONET*, prototype versions are being tested with aggregated route networks from Berlin and Munich (Mathias, Fellendorf, and Vortisch, 1999). It is composed of statistical models for the evaluation of historical sensor data and traffic demand, and of a dynamic traffic assignment model and mesoscopic traffic simulation. The dynamic assignment is carried with a modified version of the *Path Flow Estimator* (*PFE*, developed within the CLEOPATRA project), while the mesoscopic simulation is done using the *DYNEMO* model. In addition, tests are performed with a new dynamic route choice and assignment model, developed by Mathias, that is based on recurrent neural networks. The authors report encouraging results but mention that work must still be done to increase the size of networks that can be handled and augment the precision of travel time estimates.

3.5 Conclusion

ATIS is the ITS component directly reaching the public. In the public eye, ATIS=ITS. It is thus the component having the highest commercial potential. There is a definite trend toward integration with other service components such as parking selection and payment, electronic toll collection and yellow page services. However, while many studies show that travellers are now ready to pay for an information service, they will also be prompt to abandon it if the information they are given is not reliable, accurate and timely.

As for the impact of ATIS usage on traffic flows and network efficiency, it is probably very difficult to quantify it at this time. Apart from the fact that many factors enter into the equation and interact in often unpredictable ways, the deployment of ATIS is still at a fairly early stage and several developments have yet to take place. For one thing, travellers have to develop their confidence in the deployed systems before they start relying upon them in regular fashion. It is also clear that ATIS will become more effective over time, as more and more sophisticated tools become imbedded into them. It would thus be premature to draw conclusions on the *potential* effectiveness of ATIS solely by looking at systems currently deployed. This being said, the analyses based on existing ATIS systems tend to show a measurable positive impact (Ashida, Kawamoto, and Kenishi, 1999; Kubota, Higuchi, and Watanabe 1999; Wunderlich, Bunch, and Larkin, 2000).

IV. FREIGHT TRANSPORTATION

The development of Intelligent Transportation systems and technologies dedicated to the movement of goods, freight vehicles and services is closely related to the evolution of the freight transportation industry, particularly relative to the penetration and utilisation of information technologies, in response to the tremendous shift in commercial and industrial practices of the last decade.

New challenges for the transportation industry resulted from the major changes affecting supply chains and logistical processes in trade and commerce. The first change may be attributed to the impetus toward inventory reduction that led to the "Just-in-Time" procurement practices and, more recently, to just-in-time replenishment of goods in the retail industry. The procurement and distribution of goods has also been significantly influenced by the powerful trend toward the globalisation and liberalisation of markets and the creation of free trade zones. Agreements between countries over wide geographical regions such as Europe and North America have already resulted in the creation of a number regional or continental free trade zones, such as the territory defined by the North American Free Trade Agreement (NAFTA) composed of Canada, USA, and Mexico. And the movement is far from exhausted. The liberalisation of markets has been accompanied by a restructuring of manufacturing and distribution channels world-wide. Production units are re-located and the components required for final assembly of complex industrial products might be brought in from many distant locations. In the same time, trans-national centralised warehousing facilities and value added distribution centres are changing the flows of goods on the American and European continents.

The contemporary wave (some prefer to speak in terms of "tsunami") of Internet and electronic commerce development points towards a renewed epoch of major transformations for the freight transportation industry. We are witnessing the beginning of these transformations, of which the most immediate manifestations are the modifications to the logistic chains and practices of several major industries, the increased demand for transportation resulting from individual consumer electronic commerce, and the proliferation of electronic websites points where shippers and carriers may meet and close deals. Nobody may predict today the final magnitude of the transformations to the way we perceive transportation and to the planning and operating practices and tools of freight carriers. We believe they will be significant. And the industry will rely on the same enabling technology deployed for ITS. ITS will become, in fact, an enabling technology for the efficient and smooth operations of (part of) the electronic information society.

These changes have certainly resulted in, and continue to foster a, higher demand for transportation. They also increase the requirements for freight transportation services in terms of enhanced customer value: reduce transportation and distribution costs, while responding to the customer needs in terms of delivery time and reliability. These factors put tremendous pressure on freight carriers (including management of fixed infrastructures such as ports, airports, inter-modal platforms, etc.) to reduce and control costs, to plan and operate efficient, timely, and reliable services, to react rapidly to new customer requests, emerging or shifting business opportunities, changes in the economic and regulatory environment.

A significant part of the answer the freight transportation industry offers to these challenges is based on information and decision technologies: two-way communication, location and tracking devices, electronic data interchange, advanced planning and operation decision support systems. Intelligent Transportation Systems integrate and enhance these technologies within the firm, as well as through the linkages and exchanges between the firm and its environment (customers, partners, regulators, etc.)

It is convenient to examine ITS for freight transportation according to the scope of the particular systems: *Commercial Vehicle Operations* (*CVO*) for system-wide, regional, national, or continental applications and *Advanced Fleet Management Systems* (*AFMS*) dedicated to the operations of a particular (group of) firm(s). Although different in scope, both categories of systems require a number of enabling technologies, some of which are already firmly established, some that are still emerging. A brief description of freight transportation systems (Crainic, 1999) precedes the presentation of accomplishments, trends, and challenges in the CVO and AFMS domains.

4.1 Freight Transportation

Demand for freight transportation derives from the interplay between producers and consumers, and the significant distances that usually separate them. Producers of goods require transportation services to move raw materials and intermediate products, and to distribute final goods in order to meet demands. Producers of services also require transportation to receive the materials they need and often to reach their customers. Carriers supply transportation services. Railways, shipping lines, trucking companies, and inter-modal container and postal services are examples of carriers. Considering the type of service they provide, ports, inter-modal platforms, and other such facilities may be described as carriers as well. Shippers are either the producers or some intermediary firm that joins demand to supply. Governments contribute the infrastructure, regulate (e.g., dangerous and toxic goods transportation), and tax the industry.

When examining freight transportation, one often distinguishes between producers that own or operate their own transportation fleet (who then become carriers for their own freight), and "for hire" carriers, who perform transportation services for various shippers. From an ITS point of view, a more interesting and practical classification differentiates between:

(1) The transportation system of a region and the transportation services of a particular carrier; this corresponds to the CVO versus AFMS distinction introduced earlier on.

(2) Long haul transportation and pick up, delivery, and distribution problems.

(3) Customized and consolidation transportation.

Pick up, delivery and, more generally, distribution problems are often grouped under the appellation Vehicle Routing Problems (VRP) and usually address issues related to "local" movements between terminals and customers (Crainic and Laporte, 1997). Vehicle routes usually start and end at the same depot and are made up of several pickup and delivery operations or a combination of both. VRP-type of transportation activities are thus performed over relatively short distances and time periods. Vehicle routing operations are essential components of distribution systems and complement long haul transportation activities.

Truckload trucking offers a typical example of door-to-door, *customised* long distance transportation. In this mode, a vehicle -- truck -- is usually dedicated to each customer. When the customer calls, a truck with a driver or driving team is matched to the load and dispatched to move it. The truck is moved to the customer-designated location, and is loaded. It then moves to the specified destination; this is the long haul transportation operation. At destination, the truck is unloaded, and the driver calls the dispatcher to give his position and request a new assignment. The dispatcher may indicate a new load, ask the driver to move empty to a new location where demand should appear in the near future, or have the driver wait and call later. The truckload carrier thus evolves in a highly dynamic environment, where little is known with certainty regarding the future demand. Service is tailored for each customer and the timely assignment of vehicles to profitable demands is of outmost importance. Efficient resource management and assignment methods coupled to information and decision support systems are required to fulfil this goals and maximise the volume of demand satisfied (loads moved), and the associated profits, while making the best use of the available resources: drivers, tractor and trailer fleets, etc. Navigation services ensured by for-hire ships share some of these dynamic and stochastic characteristics.

When demands of several customers are served simultaneously by using the same vehicle or convoy, one cannot individually tailor services for each customer. Carriers must establish regular services and adjust their characteristics - routes, stops, frequencies, speeds, etc. - to satisfy the expectations of the largest number of customers possible. To increase the efficiency of resource utilisation and the frequency of service, carriers also use a number of terminals where cargo is consolidated in vehicles and vehicles are grouped into convoys or simply moved from one service to another. Externally, the carrier then proposes a series of routes, or *services*, each with its operational characteristics, often grouped in a *schedule* that indicates departure and arrival times at the stops of the route. Internally, the carrier builds a series of rules and policies that affect the whole system and are often collected in an operational (or load, or transportation) plan. The aim is to ensure that the proposed services are performed as stated (or as close as possible) while operating in a rational, efficient, and profitable way. Less-Than-Truckload (LTL) motor carriers, railways, inter-modal container shipping lines, postal and express shipment services, and so on perform such transportation services identified as service or *consolidation* transportation. (It is interesting to note that for customers, inter-modal container transportation is a door-to-door service even though the internal operation of the firm corresponds to consolidation transportation; a similar observation may be made for express letter and small package services).

A constant characteristic of freight transportation systems, especially long distance ones, is the need to move empty vehicles. This follows from the imbalances that exist in trade flows and that result in discrepancies between vehicle supply and demand in various zones or terminals of the system. The phenomenon is particularly critical to consolidation transportation firms. To correct these differences, vehicles must be moved, *repositioned*, in order to have them available to satisfy the demand of the next period. In most cases, the decision of how many and where to send vehicles is complicated by the very large number of feasible alternatives, the uncertainty of future supplies and demands, the search for the most economic strategy, and the short time available for decision. Information technologies and advanced planning and operation decision support systems are critical factors for efficient and profitable operations.

4.2 Commercial Vehicle Operations (CVO)

The CVO area of ITS has been defined as "*Advanced systems aimed at simplifying and automating freight and fleet management operations at the institutional level*". National or regional authorities, in collaboration with carriers and firms that propose the required technologies, usually initiate CVO projects. The goal is to increase the performance of the highway and customs systems and to enhance the efficiency of commercial vehicle operations by offering seamless operations through vehicle and cargo identification, location and tracking, pre-clearance and in-motion verifications. The importance of CVO type of applications has been acknowledged quite early on in ITS history, and a significant number of CVO projects have been undertaken or are currently under way.

A major class of CVO projects, particularly active in North America, concerns the operations of border crossings. The main goal is to clear drivers, vehicles, and cargo in order to speed up the passage of trucks carrying manufactured and agricultural goods between Canada and the United States and between the U.S.A. and Mexico. This has to be achieved without jeopardising the main role of the border controls regarding immigration, safety, illicit cargo, and agricultural controls, etc.

Through programs sponsored by U.S. federal authorities (e.g., the *North American Trade Automation Prototype – NATAP –* and the *International Border Clearance Program*), several operational tests of ITS technologies are conducted at border crossings between the U.S.A. and Mexico as well as between Canada and the U.S.A. (Ericson and Johnson, 1996; Easley and Flanigan, 1997). The test sites have been selected to represent a wide range of situations in terms of volume and composition of flows, location and layout, etc., as well as for their relevance to the NAFTA and other major trade corridors.

Although aiming for similar functionality and capabilities, the technologies that are used are location-specific. Two examples illustrate this observation. The *Expedited Processing and International Crossing* (*EPIC*) test in Nogales, Arizona, integrates EDI, transponders (for automated vehicle identification), licence plate readers, electronic seals (for cargo integrity), traffic management (to address congestion issues), and weight-in-motion, and links to the U.S.A. domestic *SAFER* (*Safety and Fitness Electronic Records*) CVO data base. The *IBEX – International Border Electronic Clearance –*, located at the Otay Mesa, California, crossing integrates more advanced technologies, including Automated Vehicle Identification and Classification, Automated Credential Verification, Global Positioning System, and accommodates the technologies of both PrePass and NORPASS systems. The same issues of compatibility and inter-operability among different technologies are also of foremost interest in the larger CVO context.

Initial deployment efforts of CVO technologies have been organised around the so-called "corridors". A corridor is typically organised around a major highway, or a system of highways, that cross several regional or national jurisdictions. The goal is to increase the fluidity of truck traffic and to offer seamless interstate or inter-nation border crossings, while ensuring adequate levels of control and reports relative to regulations on safety, traffic, customs, and so on. Weight-in-motion scales, overweight detectors, EDI, automatic vehicle (and cargo) identification and classification systems, vision technology (to read license plates), variable message signs are among the main technologies used. Corridor projects usually involve national and local

governments and agencies, private technology providers (that, sometimes, also contribute significantly to the financing of the technology deployment), and, obviously, motor carriers.

Several corridor projects have been initiated in the second half of the 90's, including

- The Oregon's *Green Light project* (Krukar *et al.*, 1995) that aimed to offer seamless interstate border crossing between Oregon and Utah and electronic pre-clearance on Interstate 84. Lately, Oregon, Washington, Idaho, and Utah formed the *Multi-jurisdictional Automated Pre-clearance System* (*MAPS*) and signed an interoperability agreement with the Advantage CVO program that allows participating carriers to either system to obtain automated clearance on the other network (Kelly, 1999).
- The *PrePass program* initiated in 1995 along California I-5 highway and rapidly expanded to include Arizona, New Mexico, Oregon, and Wyoming. The program continued to expand and, eventually, included most of the western states. Recently, Tennessee left the Advantage CVO program and joined PrePass. Other eastern states followed and a PrePass east-west CVO corridor along highway I-40 is now almost completed (Kelly, 1999). The program now covers 16 U.S. states and has equipped 55 weight stations with commitments for 33 more. Some 80 000 trucks are registered with the PrePass system (Slevin, 2000).
- The *Advantage CVO program* started in 1994 and now covers an area along Interstate 75 in the U.S.A. and Highway 401 in Canada from Florida to Ontario. Together with the MAPS states, it forms the *North American Pre-clearance Automated Safety System* (*NORPASS*). Some 10 000 trucks are enrolled in this system that offers 21 stations in operations with commitments for an additional 29 (Slevin, 2000).
- The *TruckScan system* installed in the state of New South Wales in Australia (Reid and Myers, 1996) uses visual recognition systems coupled to electronic databases, in-motion screening testing for weight (per axle and overall), length and height, and vehicle guidance signs and tracking systems. This passive system is designed to automate and improve the roadside checking of vehicles.

CVO systems have come a long way in the last years. Not long ago, these systems were still considered as experimental. Moreover, even though many carriers were aware and approved of several specific technologies - weight-in-motion, automatic toll payment, pre-clearance of drivers and vehicles, in particular -, their awareness of the broader scope of ITS appeared rather low (Kavalaris and Sinha, 1996). Currently, the potential benefits for authorities and users start to be clearly assessed (Zavergiu and Johnson, 1999), at least in North America. Moreover, while only a limited number of trucks are registered with a CVO program, the figures are getting impressive and continue to grow.

A number of issues have still to be addressed, however. Standardisation and inter-operability is still a main issue since technologies evolve at a very rapid pace and they are often not compatible from one project to the other. Efforts are being made, however. Thus, for example, the transponders used in the PrePass and Advantage systems are compatible, and used in other systems as well (e.g., regional electronic toll-road systems), even though there is no inter-operability agreement between the two. The issue becomes even more sensitive when examined at the continental, NAFTA or European, level. The *Parcelcall* project aims to produce over two years (2000 to 2002) a scalable, intelligent, end-to-end tracking and tracing system for transportation and logistics that may operate across borders, carriers, and transportation modes

[Wpcal]. The project is part of the Fifth Framework Program of the European Community. The team relies on thinking tags, compact, reusable devices that include sensors, two-way communication capabilities, computing power and memory and that may be attached to parcels. These tags will "probe" the parcel's environment (e.g., deviation from route or prescribed temperature) and communicate via mobile communication networks with fixed sensors and central data repository and processing units.

What information to register on the automatic vehicle identification devices constitutes another contentious issue. Some of the most advanced systems rely on significant information being provided by the electronic identifier of the truck or container. Yet, carriers are wary of information and systems that might contribute to a greater control of their operations by authorities or to more efficient taxation procedures.

The costs associated to such systems constitute another challenge. On the one hand, there are the investments in initial infrastructure construction/upgrading and CVO technology deployment and the subsequent maintenance costs. The PrePass (HELP Inc.) and NORPASS business models in the U.S.A. illustrate two approaches to this issue. In both cases, the consortia group state authorities, trucking associations, and other stakeholders, as well as a major corporation. In the first case, the corporation pays for the initial investment and maintenance in exchange of receiving the fees collected each time an equipped vehicle receives an automatic clearance at a weight station (there is a per clearance fee with a daily cap). In the latter, the services offered are the same, but the states cover the initial investment and the ongoing maintenance fees. In both cases, the participation and investment of private corporations has been a significant enabling factor, as have been the co-operation of trucking associations, and to willingness of carriers to pay for CVO services (Slevin, 2000). These types of approaches, that recall most agreements for the construction of new road infrastructures equipped with electronic tolls (and other ITS devices), show how investment issues may be addressed.

The inclusion of CVO activities in the national ITS architectures developed for the U.S.A., Europe, Canada, and Japan constitutes a clear indication of the importance of this area. It also constitutes one of the means to overcome the difficulties associated with ITS/CVO and to facilitate deployment. The *Commercial Vehicle Information Systems and Networks* (*CVISN*) project belongs to this group. It is a major project undertaken by the U.S. DOT and the Federal Highway Administration, in collaboration with the Johns Hopkins University and several private corporations, motor carriers, and agencies in many states. The goal is to detail the U.S. national ITS architecture regarding its CVO components, and offer states a framework to help them define projects to deploy new CVISN capabilities (McGarigle, 1997; Rickeson, 1999).

To conclude this section, note that customised Advanced Traveller Information Systems aimed at the particular needs and operations of commercial carriers also start to be proposed. A private-public partnership proposes such a system for the State of Arizona. The system is planned to electronically deliver to registered vehicles and carriers real time travel information concerning congestion, incident occurrence and location, road construction, driving restrictions, and so on. Wireless and the Interned (web site) are the preferred main modes of information dissemination. Customised routing is to be offered based on predicted time-dependent travel times (obtained by using the state-wide TrafficCast traffic predictions – [Wtcast]) and driving restrictions. It is predicted that the system will improve routing and dispatching for carriers and help reduce congestion in general.

It is thus to be expected that the deployment of institutional ITS CVO systems will continue and probably accelerate.

4.3 Advanced Fleet Management Systems (AFMS)

The second type of ITS applications corresponds to "*Advanced systems aimed at simplifying and automating freight and fleet management operations at the carrier or business-to-business level*", or AFMS for short. Similar to many other ITS areas, development proceeds along two major, parallel but complementary, directions. The first concerns the electronics, location, tracking, and communication **hardware** and associated information technology software; The second, the **methodologies** – models and algorithms – required to process the data and transform it into timely and meaningful information and intelligent advice for **advanced fleet and operations planning, management, and control systems**.

One may argue that the developments in the first class of applications started with the adoption by the freight transportation industry of EDI, two-way communication, and vehicle (and cargo) location and tracking technologies (Roy, Bigras, and Crainic, 1997). This line of developments is still going strong, its current focus being on wireless communications, the use of Internet, and the integration of various technologies, in-vehicle location and communication equipment combined to Internet access to the company data for major customers (e.g., Hook, 1998).

EDI can be defined as the inter-organisation, computer-to-computer exchange of business documentation in a standard, machine processable format (Emmelhainz, 1990). Its popularity has grown rapidly due to several benefits associated with its use: minimisation of manual data entry, increased transaction speed and accuracy, lower communication costs, and promotion of simplification of procedures (Anderson *et al.*, 1994). Major shippers (e.g., the auto industry) and large carriers or infrastructure managers (container carriers, port authorities, railways) have initially promoted the utilisation of EDI in the transportation industry. Although the trucking industry has been slower to develop its EDI capabilities, the number of motor carriers offering EDI services in USA has increased significantly in recent years (Sunstrum and Howard, 1996) mainly to satisfy customer requirements, increase customer service, and remain competitive (Allen, Crum, and Brauschweig, 1992; Johnson, Allen, and Crum, 1992; Walton, 1994).

Pre-clearance activities along CVO-equipped corridors or regions also require the utilisation of EDI for information transmission among shippers, carriers, and various officials. This reinforces the observations that there has to be a critical mass of EDI users in the market before it is financially justifiable (Giannopoulos, 1996; Udo and Pickett, 1994), and that investing in technologies such as EDI may only be profitable when these technologies are fully integrated with other systems within the organisation (Ratliff, 1995).

EDI has been one of the strongest initial enabling factors of large partnerships and alliances between large number of carriers and shippers, before "electronic commerce" became a household name. This trend is actually leading to the electronic integration of carriers (including inter-modal transfer facilities) and shippers with common interests in the movement of certain commodity groups or the utilisation of particular infrastructures. Information technologies and appropriate planning and operating management tools are required to support and enhance such virtual business-to-business communities of interest. The *European Cooperative Resource*

Management of Unit Loads (*COREM*) is an example of such efforts. The basic idea is to use multimedia communications and handling of multimedia documents to allow several administrative units – in the same or in different companies – mange and co-ordinate the utilisation of the same pool of resources. Pilot projects have addressed co-operative resource management between branch offices of the same carrier, between a motor carrier and a maritime shipping company, between truck operators and ferry or port authorities. Client/server architectures, ISDN, and EDI/EDIFACT messages are major enabling technologies. The initial results are very encouraging. *Trident* (*TRansport Intermodality Data Sharing and Exchange Network*) is another project that targets some of the same goals [Wtrid]. Within ERTICO, the project aims to develop over the 2000 to 2002 period common and reusable mechanisms that enable sharing and exchange of data between transport operators of different modes. These projects are a clear illustration of the worldwide tendency towards standardisation as well as towards the globalization of projects and expertises.

Vehicle and cargo tracking devices, wireless communications and on-board computers are essential to efficient operation and quality customer service. At the end of the 80's, major carriers had already started to equip their fleets. Thus, Schneider National, a major U.S. truckload carrier, invested some $20 million to launch its system back in 1988 and equip its fleet with on-board computers and satellite communication devices. Its use of technology has reportedly resulted in cost reductions in the order of 24% and increased on-time performance from below 90% to about 99%. Using satellite communication, Schneider can track the location of each vehicle anywhere in the United States and dispatch it on a real time basis to satisfy customer needs and adapt to unforeseen changes. This tracking ability has enabled the company to reduce empty mileage by 25%. Drivers are no longer wasting time locating pay phones to contact their home base for instructions. They receive directions and information about pick-up and delivery procedures on their computers via satellite. The use of on-board computers also enables Schneider to monitor vehicle speed and driver working hours in order to comply with laws and regulations. As a result, technology has helped reduce the company's accident rate by 35% since 1987 (Cohen, 1995). A similar experience in reported by Vos Logistics, a large European transportation company operating throughout the whole continent and often hauling just-in-time loads. A comprehensive satellite-based tracking and communication system permits the fleet managers to continuously monitor the status of each truck and container. Land communication lines also link fleet managers to the warehouses and offices of the company. The computing equipment installed in each truck (at a cost of around US $4,800 per truck) not only enables the tracking and driver communication functions; It also monitors and transmits statistics on driver hours, kilometres travelled, fuel consumption, and so on. This information is then processed by dedicated software to allow fleet managers to plan maintenance schedules. The location and status of each vehicle is also available to planners who match vehicles and loads. Increased service quality, productivity, and ultimately, profitability were the main goals motivating the investment. A first gain in customer satisfaction was obtained directly by offering high volume customers real-time access to the company's tracking system allowing them to obtain information on the location and expected arrival time of their loads (Hook, 1998).

Success stories such as these, combined to customer requests for the possibility to know, at any moment, where one's load is, have accelerated the penetration of satellite positioning, vehicle tracking, two-way communication technologies, and in-vehicle equipment for communication, computing, and monitoring in North American (Hall, 1996; Roy, Bigras, and Crainic, 1997) and European (Grant, 2000) companies. The continuous improvement of the

Global Positioning System (GPS), combined to the integration of GPS and communication technologies and the resulting improvement in the quality of systems (up) and their prices (down), means wider acceptance of these technologies and their utilisation in many modal and inter-modal settings (Grant, 2000), as well as their penetration in countries outside the well-developed regions (Barnes, 2000). Electronic commerce and Internet both accelerate the penetration of these technologies and increase the challenges associated to their acceptance and efficient utilisation (Golob and Regan, 2001). The trend is, however, irreversible.

Once the fleet is equipped and linked to the dispatchers' computers and company's data processing and storage infrastructure, a huge quantity of data becomes available for immediate decisions and background analysis and planning activities. Advanced Fleet Planning and Operation Systems aim to (1) process this information, received through the Internet, EDI, communication, tracking systems, etc., and (2) integrate it to the current transportation plan and customer requests to achieve a more timely operation, efficient allocation and utilisation of the fleet, and satisfaction of customer requests. Differently put, similarly to other ITS areas, hardware and communication technology developments have driven the development of Advanced Fleet Management Systems. There is the need to infuse these systems with **intelligence**. Indeed, a recent study (Mahmassani *et al.*, 2000) shows that if 60% of major U.S. carriers are equipped, only a small number is using this information to support fleet operation decisions. This need is more and more widely acknowledged and it is directly reflected in the national ITS architecture proposals of the USA, Canada, Europe, and elsewhere.

Operations Research approaches and methodologies have for quite some time now demonstrated their central role in designing efficient and powerful decision support systems for the planning and operations of transportation systems (Crainic, 1999) and are also uniquely positioned to assist the transformation of the huge quantity of data provided by in-vehicle systems into timely and meaningful information and intelligent decisions for ITS/CVO operations. Operations Research principles, models, and methods are increasingly found at the core of Advanced Fleet Management Systems. The following section reviews efforts already implemented or under way and examines research and development avenues of great potential.

4.4 Operations Research and ITS/CVO -AFMS

Developments, challenges, and opportunities for ITS/CVO- AFMS and Operations Research occur both at the level of a carrier and for groups of carriers, shippers, and agencies joined together through business-to-business networks. A number of applications already exist. Some are implemented at actual firms. Most still appear as proposals and prototypes out of research centres and laboratories. Much more may be accomplished, however. In the following, we attempt to single out a number of important probable and feasible developments that will use the ITS infrastructure and architecture to do more and perform better.

For a firm, the various decisions and management policies affecting its development and operations are often classified according to three planning levels:

1. Strategic (long-term) planning typically involves the highest level of management and requires large capital investments over long-term horizons. Strategic decisions determine general development policies and broadly shape the operating strategies of the system: design of the physical network and its evolution, acquisition of major resources, definition of broad service and tariff policies, etc.

2. Tactical (medium-term) planning aims to determine, over a medium-term horizon, an efficient allocation and utilisation of resources to achieve the best possible performance of the whole system. Typical tactical decisions include issues related to the determination of the routes and types of service to operate, service schedules, traffic routing, repositioning of the fleet for use in the next planning period.
3. Operational (short-term) planning is performed by local management (e.g., dispatchers) in a highly dynamic environment where the time factor plays an important role. Important operational decisions concern the implementation and adjustment of schedules for services, crews, and maintenance activities, the routing and dispatching of vehicles and crews, the dynamic allocation of scarce resources.

Most current developments and a significant part of probable future applications address operational issues, load matching and resource allocation, dispatching, and routing, in particular. The principal goal of these systems is to offer the possibility to control and co-ordinate operations in real-time.

Indeed, in a typical large or medium-sized city, many private firms and public organisations operate fleets of vehicles of different types to cater to various needs of the population: emergency vehicles (fire trucks, ambulances, etc.), police cars, commercial delivery vehicles, taxis, courier fleets, etc. While some of these fleets have to perform tasks that may be known well in advance or sometimes repetitive (e.g., some fleets performing commercial deliveries), it is important to note that many of them operate essentially in a demand responsive mode: the demands to be serviced are not known beforehand and the fleet has to be deployed and managed in real-time to handle them as effectively as possible. Moreover, the deployment of ITS technologies, in particular accurate positioning devices and in-vehicle computing and communication equipment, opens up the possibility of enhanced customer service and increased productivity by re-routing vehicles in real-time to serve new requests.

Carriers that ensure interurban, long haul transportation services also evolve in highly dynamic environments and face similar challenges. Full-load motor-carriers and container transportation companies offer typical examples of such requirements. On the one hand, most demands for empty vehicles arrive dynamically, are very difficult to forecast accurately, and require instantaneous decisions (the customer is on the phone or Internet line) regarding the most appropriate combination of vehicle, tractor, crew, etc., that will service the demand. On the other hand, once a vehicle has completed its current task and is empty a decision has to be made concerning its next assignment: service a new customer demand, reposition the vehicle for some future, forecast request, etc. Each such "local" decision has a non-negligible impact on the future deployment of the fleet and thus on the long-term efficiency and profitability of operations. Moreover, the complexity of the impact evaluation is further aggravated by the length of the planning horizon, significantly longer in interurban operations than for urban transportation (up to a week compared to one day).

It is thus normal that a significant line of research addresses the issues of real time dispatching, routing, and re-routing of vehicles in response to changes in demand, travel time, congestion, or other conditions of travel conveyed via Advanced Traveller Information Systems, truck-dedicated or aimed at all traffic classes, and wireless or on-board communication devices. See Séguin *et al.* (1997) for a general framework for Operations Research methodologies in real-time decision-making.

Traditionally, the organisations facing real-time demand have relied on human dispatchers to manage their fleets. As with any other system relying heavily on human intervention, the performance of these fleets was thus strongly dependent upon the quality and the experience of their dispatchers. Among other factors, cognitive limitations make it extremely difficult for human dispatchers to effectively monitor and control fleets made up of a large number of vehicles, a situation frequently encountered in many applications. From a modelling standpoint, fleet management problems correspond to combinatorial optimisation problems (e.g., vehicle routing, covering, or design problems) that are notoriously difficult to solve, even in a static context (Crainic, 1999; Bertsimas and van Ryzin, 1991, 1993; Gendreau and Potvin, 1998; Powell, 1988; Powell, Jaillet, and Odoni, 1995). This, coupled with real-time requirements, explains to a large extent the reliance up to now on human dispatchers. Fortunately, recent developments on the algorithmic side, in particular the emergence of powerful *metaheuristics*, and advances in computing technology, in particular distributed and parallel computing, now make it possible to contemplate tackling in real-time large combinatorial problems in a reasonably effective way. In fact, the main stumbling block in most AFMS applications is the need to handle dynamic (stochastic) data (whether these are demand patterns or problem parameters).

Interestingly enough, it seems that in several applications simple schemes can be devised to address this issue. The simplest that one can come up with is certainly to base current decisions on current information. Actual experiments with this scheme in the context of courier applications showed that it could be surprisingly effective (Gendreau et al., 1997; Gendreau et al., 1998). This conclusion is in stark contrast with observations in many fields, including ATMS/ATIS and most CVO-AFMS problem classes. Indeed, such a myopic strategy cannot account for the future consequences of current decisions and are generally dominated by policies that incorporate look-ahead capabilities (e.g., Powell, 1988; Yang, Jaillet, and Mahmassani, 1999).

The class of dynamic vehicle routing formulations offers a methodological framework to many real-time routing problems encountered in the CVO-AFMS domain. As already mentioned, these are difficult problems to solve (Bertsimas and van Ryzin, 1991, 1993; Powell, Jaillet, and, Odoni 1995). Yet, metaheuristics, and particularly Tabu Search (Glover and Laguna, 1997), have demonstrated their ability to adequately address these challenges (Crainic and Laporte, 1997; Gendreau and Potvin, 1998; Gendreau, Laporte, and Potvin, 1997). Most applications address "local"-area problems, which are cases where the geographical region is limited and vehicles (and drivers) return at their home bases at the end of the day. Distribution and pick up and delivery problems in urban zones belong to this large class of applications, which includes the local operations of inter-urban LTL firms. It is also in this context that most of the studies aimed at real-time dispatching and routing of vehicles have been undertaken. Shen *et al.* (1995) developed a dispatching system for a courier company based on neural networks and learning abilities. Gendreau *et al.* (1996a,b) propose an adaptive memory Tabu Search method and a parallel implementation that ensures an efficient optimisation of the routes. Experiments performed using a discrete-time simulator have shown the superiority of sophisticated optimisation procedures to handle real-time demands as compared to simpler methods, classical insertion heuristics in particular (Gendreau and Potvin, 1998).

Dynamic traffic simulation offers an alternate approach. Simulation certainly offers the tools to explore and validate operating strategies. Its precise role in actual real-time dispatching and

routing of vehicles has yet to be assessed however. The challenges here are very similar to those of the ATMS area. The initial exploration of the subject by Taniguchi, Yamada, and Tamagawa (1999) is an encouragement to further pursues this direction.

Very few efforts have been dedicated to real-time re-routing of vehicles to satisfy new demands over larger geographical regions and longer time frames. Reagan, Mahmassani, and Jaillet (1995, 1996a,b) explore various local rules for the dynamic assignment of loads under real-time information. Simulation experiments tend to indicate that these rules perform relatively well in a stochastic environment (Reagan, Mahmassani, and Jaillet 1998). Additional comparisons to a rolling-horizon, dynamic assignment formulation offer interesting but intriguing results (Yang, Jaillet, and Mahmassani, 1999). On the one hand, advance information appears valuable in re-assignment of vehicle to loads while, on the other hand, forward-looking strategies appeal less interesting when congestion is high and the time future loads are known in advance is significant. Clearly, much more research is required in this area.

The studies mentioned in the preceding paragraph address issues that belong to the large class of dynamic fleet management problems (Crainic, 1999; Crainic and Laporte, 1997; Powell, Jaillet, and Odoni, 1995). Here, dynamically allocate limited resources are dynamically allocated to requests and tasks: empty vehicles, trailers and rail cars are allocated to the appropriate terminals, motive power tractors and locomotives to services, crews to movements or services, customer loads to driver-truck combinations, empty containers from depots to customers and returning containers from customers to depots, and s on. Dynamic and stochastic network formulations have been, and continue to be, extensively studied for these problems. This has resulted in important modelling and algorithmic results, a number of which have been transferred to industry (e.g., Powell *et al.*, 1992). Based on these results, the LQN (*Logistics Queueing Networks*) methodology has recently been proposed (Carvalho 1996; Powell *et al.*, 1995) to simultaneously manage, in real-time when required, several resources (Powell and Carvalho, 1998a,b). This is an extremely rich field for research, development, and applications, and it naturally dovetails the CVO-AFMS area.

A critical issue in real-time settings is that of response time. In situations such as emergency vehicle management, there is no time to compute an efficient response when a call is received. This does not, however, preclude the use of deliberate decision-making to optimise this response: one simply has to find ways of anticipating future events in an effective fashion. Thus, for example, one may combine data processing and forecasting methods, optimisation-simulation models, and decision heuristics into comprehensive decision-support systems: The optimisation-simulation models continuously generates and evaluates future conditions and deployment scenarios, while rapid, simpler heuristics respond in real-time to customer requests or changing conditions (congestion, accidents, and so on). Note, however, that this may result in significant computational requirements, since one has to prepare for many potential outcomes. Parallel computing may help address this issue as well as provide more robust solutions to mathematically difficult problems.

While custom-service transportation firms, such as truckload, container, and express courier companies, appear as prime beneficiaries of ITS, consolidation-type carriers, railroads, LTL motor carriers, and inter-modal facilities, for example, may also attain substantial gains by using advanced information and decision technologies. Of course, the local, pick up and delivery operations of these firms are similar to those described earlier on and would enjoy the same benefits. Similarly, the control in real-time of vehicles during their long-haul journeys (trucks

speeding on highways or the pacing of trains) may be significantly improved by the use of ITS technologies.

A very promising research and development avenue consists in a better integration of the information obtained in real-time and the planning and dispatching tools and systems available to consolidation-type carriers. We have already mentioned the possibility to re-route a vehicle already dispatched to serve a new customer or to avoid a congested area (due to an incident, for example). Driver and vehicle assignments may be more efficiently planned and performed when accurate data is readily available, as is empty vehicle management. Another area of potential benefits is in a more efficient scheduling of terminal operations and resources. Thus, for example, a terminal working schedule that smoothes out the workload and reduces overtime and terminal congestion could be produced through an analysis of dispatch decisions at the various terminals in the network, combined to real-time data on the location and load of the vehicles and the results of the optimisation-based scenario analysis described above. Similarly, more accurate data is available for adjusting the maintenance planning process to real-time events during actual operations. Not many studies have been dedicated to these areas yet. The study of the impact of new technologies on the planning and performance of inter-modal classification yards (Bostel and Dejax, 1998) illustrates what could be achieved through a combination of advanced hardware, software, and decision technologies.

A more challenging area concerns the interactions between the planning of operations, the availability of real-time data, and the actual implementation of transportation plans in an ITS environment. A number of methodologies and decision support systems to assist the planning and operations of freight carriers exist (see Crainic, 1999, for a review). Most are based on static formulation using data currently existing in the Information System of the firm. The advent of ITS location and communication technologies described earlier in this chapter offers the possibility to dramatically enhance the quantity and quality of the data available for the planning process. The capability to evaluate and forecast demand and transportation system characteristics (e.g., travel times) should be significantly enhanced. This should translate into better plans and more profitable operations.

Significant research efforts are required to adequately model the various planning and management problems under ITS and real-time information, and to develop efficient solution methods. One challenge concerns the dynamic service network design: assuming the transportation plan is known, decide on the departure of each vehicle (or service) given the current data and the forecast demand and traffic conditions. This class of problems takes the form of very large-scale combinatorial optimisation formulations, which are difficult to solve. A combination of decomposition techniques (such as LQN), metaheuristics, and parallel computation appears to offer a promising solution approach. Another fascinating direction, and one that could yield considerable benefits, concerns the re-engineering of the planning process to better take advantage of the data availability and the possibility to rapidly adjust service to changing conditions.

Parallel and distributed computing is an enabling factor for ITS in general and CVO-AFMS in particular. Its challenges are of two different but complementary natures. On the one hand, parallel computing offers the possibility to design data analysis and decision support system architectures to efficiently answer complex requests in real, or quasi-real time. Thus, processors may be dedicated to the various tasks of receiving, validating, and formatting data, analysing and aggregating it, forecasting, background simulation-optimisation, real-time selection of the

appropriate strategy, etc. On the other hand, parallel computing also offers a challenging perspective with potentially great rewards: to solve realistically formulated and dimensioned problem instances within reasonable times. Each class of problems and algorithms presents its own challenges. It appears clearly, however, that research efforts have to be dedicated both to the decomposition and distribution of tasks corresponding to one particular problem instance and algorithm, and to the development of co-operating search mechanisms that bring to bear on any given problem instance the combined power of several exact methods and metaheuristics. These ideas that have just begun to be considered (e.g. Séguin *et al.*, 1997), have a great potential for the development of intelligent and efficient decision support tools for ITS and other real-time transportation systems.

We conclude this section with a few reflections regarding the linkages between CVO-AFMS and electronic commerce. The definition and development of Intelligent Transportation Systems concepts and technologies started well before the business community realized the potential of Internet-based operations and electronic commerce started to penetrate the business-to-consumer and business-to-business exchange world. The two domains share several characteristics, however, as well as a number of enabling technologies. Referring to the latter, both application areas require computing equipment, powerful communication means, and intelligent software to ensure smooth and reliable operations. Not all technologies are appropriate for all applications, of course. One may single out, however, the increasingly important role that wireless communications and particularly the new generation of mobile phones appear to play in both areas.

An interesting development, however, that may directly and significantly impact the operations and performances of freight carriers and their customers is the emergence of Internet-based community of interests and electronic auction mechanisms. These virtual market places that implement freight exchanges offer carriers the perspective of an easier access to loads and a smoother operations. This is certainly true for full-load carriers, but it also presents significant opportunities for consolidation-type companies, LTL motor carriers in particular. By accessing the market, loads could be obtained, thus reducing the need to move empty vehicles to balance the operations.

A number of such markets start to appear. The market mechanisms do not appear very sophisticate, however. Significant research is required in this area, particularly concerning the possibility to bid on a bundle of loads simultaneously. This *combinatorial bidding* requires more complex Operations Research mechanisms to determine load allocations and the corresponding prices. But they also offer increased flexibility and capability to participants; the possibility to bid on a set of loads that make up a closed route, for example. Other than the development of the appropriate market mechanisms, one also has to consider the support of participants, carriers particularly. Agents that search the electronic space for auctions and interesting opportunities offer one form of support. Tools that decide when a load offered on the marked is interesting, and at what price, and that integrate it into the planned operations offer the second form of support. Significant research efforts are required in all these areas. A fascinating question that will also have to be addressed is whether the access to such electronic market places will reduce the stochasticity of operations and reduce the need for sophisticated look-ahead capabilities.

4.5 Conclusions

In summary, the basic modelling and algorithmic tools, as well as the specialized real-time solution strategies, that are required for the successful application of operations research in the area of AFMS are now becoming available and open the door to a wide variety of interesting and profitable applications in this field.

The various applications described in the paper illustrate the key role operations research models and methods play in the development of the software component of ITS. Such methodologies transform the huge amount of data provided by ITS technologies into useful information that may be either distributed to the various ITS users - agencies, travellers, and so on -, or transformed into operating policies and instructions. Operations research-based data processing and decision support systems may explore and evaluate the behaviour of the transportation system under various conditions and develop contingency plans, predict the state of the system over the next time periods, generate general or user-tailored itineraries or guidance instructions, plan operations and assist the real-time management of a fleet of private or public transport vehicles.

Research and development efforts are currently under way in several of these areas. The methodological developments of recent years in the various fields of operations research, combined to recent advances in computer science, in particular in parallel and distributed computing, put the required models and methods within our reach. More efforts are still needed, however.

Particular efforts are needed to develop the software tools that will contribute to the validation and integration of the various ITS policies and software components. Indeed, similarly to the testbeds that allow in-laboratory testing of hardware components, there is a need for *software testbeds*. These would allow testing and experimentation in laboratory conditions of the accuracy and correctness of, for example, various models of user behaviour, traffic prediction, vehicle, driver or passenger routing and guidance, and so on. Experimentation could be based on either generic or actual traffic data. Parallel computing could ease the computational burden, especially when real-time data (obtained, for example, through the Internet) is used in the simulations. Such testbeds would facilitate the demonstration of new ideas, data processing, and decision support methodologies and accelerate their deployment.

V. CONCLUSION AND PERSPECTIVES

Over the last twenty years, Intelligent Transportation Systems have evolved from an ambitious concept to an emerging reality, as systems that deserve, at least to some extent, to be called ITS start to be deployed. With the definition of national and international architectures, equipment manufacturers, service providers, and transportation authorities now have a common language to describe systems requirements and means. We should thus witness in the coming years an acceleration in the deployment of ITS.

This being said, everything is not perfect in the ITS world. One area that badly needs to receive more attention in the immediate future is the validation and integration of ITS policies and software components. Dedicated software tools, "software testbeds", similar in purpose to the hardware testbeds used for in-laboratory testing of hardware components, need to be developed to assess the accuracy, correctness and efficiency of the various software components, such as user behaviour models, traffic prediction techniques, route guidance methods, etc. Such testbeds would also prove extremely useful to determine how various components interact when put together, thus avoiding costly mistakes in overall system design. Finally, they would serve an important role as demonstration tool for new ideas, concepts and methodologies.

The main problem in the recent development of ITS is that much of the focus was put on the "hardware" component of ITS, while their "software" component (models, algorithms, and decision-support systems) has somewhat lagged behind. In many cases, data provided by very sophisticated sensors and relayed through advanced communication technologies is still being processed and acted upon by human operators with little, if any, decision-support tools. There is thus a challenge to drastically increase the intelligence in ITS. As we as seen in the description of ATIS and freight transportation applications, Operations Research methods can help close this gap, but a lot of work is still required.

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ITS Webography

The Internet has become a primary and inescapable source of information. This Webography annotates some websites related to Intelligent Transport Systems. While this list is certainly not exhaustive, many of the sites given here contains links to other ITS related sites, giving a very good coverage of the field. The Internet however is a moving target and even though we have taken every precautions to ensure the accuracy of this compilation, web sites come and go at a very fast pace, outdating any webography attempt even before it reaches its audience. The Internet is a wonderful research tool, but in our so-called information society, all the emphasis is toward rapidly delivering up to date information with very little attempt to preserve it.

Europe

ERTICO

http://www.ertico.com

Site describing the ERTICO mission, objectives, organisation and a list of partners. Contains a list of ongoing european projects and "European success stories". Visited 2001/05/27

Information Society Technologies - Transport and Tourism

http://www.cordis.lu/ist/ka1/trans_tourism

Main European site describing the current research projects (1998-2002) in Europe in ITS. Contains a description of the infrastructure and a detailed list of all the projects. Technical reports and project statements are available on-line. Visited 2001/06/01

Telematics Applications for Transport and Environment

http://www.cordis.lu/telematics/tap_transport

Main European site describing the research projects conducted in Europe in telematics (ITS) from 1994 to 1998. Contains a description of the infrastructure and a detailed list of all the projects. Technical reports and project statements are available on-line. Visited 2001/06/04

EUREKA

http://www.eureka.be

EUREKA is a Europe-wide Network for Industrial R&D. Many projects are in the field of ITS. The site contains a list of project definitions and status, among which the PROMETHEUS project. Visited 2001/05/27

KAREN Project

http://www.cordis.lu/telematics/tap_transport/deployment/architecture/arch.html

Contains articles and on-line technical documents related to the European ITS system architecture. Visited 2001/06/04

ITS Standardization Procedures

http://www.cordis.lu/telematics/tap_transport/deployment/standards/standards.htm

Site dedicated to ITS standardization procedures and news. Visited 2001/01/01

CEN278

http://www.nni.nl/cen278

Official WEB site of the technical committee working on European ITS standards. Contains a list of working documents and published standards. No documents available on-line. Visited 2001/05/27

ITS-Network

http://www.its-network.com

Global meeting place and information source for the ITS community. Gives access to an on-line library, discussion forums and news headlines. Visited 2001/05/27

CORDIS

http://www.cordis.lu

Community Research and Development Information Service. Several searchable databases such as Programmes, Projects, Results and Publications. Covers a lot of R&D fields other than transport. Visited 2001/05/27

Information Market Europe

http://www.cordis.lu/ist

Information on the European Information Society Technologies (IST) programme. While not directly aimed at ITS technologies, a lot of these projects overlap with ITS technologies. Several documents and publications available on-line. Visited 2001/05/27

ISO/TC204

http://www.iso.ch

ISO ITS architecture and standards. Cannot link directly to the information, use the site search engine for TC204 commitee: ISO/TC204 Transport Information and Control Systems. Visited 2001/06/01

China

Coordination Office of China National ITS

http://www.chinaits.org/index2.html

Official Chinese ITS coordination organism. Contains a few introductory texts and links to other ITS sites. Visited 2001/05/25

China ITS Information Service Center

http://www.stic.com.cn/englishweb.htm

Main Chinese ITS information site. Visited 2001/05/25

Chinese ITS Architecture

http://www.stic.com.cn/its.htm

Paper describing the Chinese ITS architecture project (May 1998). Visited 2001/05/25

Australia

ITS Australia

http://www.its-australia.com.au

Description of the association, links to member companies and a document describing in details the ITS national reference architecture. Visited 2001/05/27

Special Interest Network for Transport in Australia - Sydney University of Technology

http://www.sinta.uts.edu.au

Contains the SINTA ITS research areas and pointers to other ITS sites. Mainly dedicated to GSM Positioning. An on-line thesis is available: Improved Positioning of Motor Vehicles Through Secondary Information Sources (PDF, Sept. 1996). Visited 2001/06/01

Institute for Transportation Studies

http://www.its.usyd.edu.au

University of Sydney Institute for Transportation Studies (ITS). Contains a list of publications that can be bought. Visited 2001/05/27

TSC Home Page

http://www.unisa.edu.au/tsc/index.html

TSC Home Page. An ITS status paper is announced (as of 1997/7/24) from Taylor, M. and D'Este, G. Visited 2001/05/27

Japan

VERTIS

http://www.tjnet.or.jp/vertis

Contains the VERTIS infrastructure description and links to VERTIS member sites. Japanese ITS architecture is described with several charts (gif files). Visited 2001/05/28

Japanese Ministry of Construction ITS Homepage

http://www.mlit.go.jp/road/ITS

Informations on Japan ITS initiatives. Contains project descriptions and status (mainly ETC, AHS and the VICS program) and links to other ITS site in Japan and worldwide. Also contains a revised on-line version of the "ITS Handbook in Japan" published by HIDO. Visited 2001/05/28

Highway Industry Development Organization

http://www.hido.or.jp/ITSHP_e

Contains ITS news headlines in Japan, links to other ITS sites in Japan and worldwide and general informations on ITS, ETC, AHS and the VICS program. Also contains on-line articles of "ITS Review". Visited 2001/05/28

Tokyo University

http://www.vml.t.u-tokyo.ac.jp/

Yoshimoto & Nakamura Laboratory Homepage. A few articles on ADS (Automated Driving Systems) are available on-line. Visited 2001/05/28

Advanced Cruise-Assist Highway System Research Association

http://www.ahsra.or.jp

Description of the mission and organization of the association. Contains videos and Flash animation on AHS advances in Japan. Also contains on-line version of presentations made at AHSRA Research Seminars Visited 2001/05/28

Universal Traffic Management Society of Japan

http://www.utms.or.jp/world/index.htm

Infrared beacon technology and traffic safety devices (detectors et al.) Visited 2001/05/28

Public Roads On-Line

http://www.tfhrc.gov/pubrds/fall96/p96au41.htm

Report on ITS history and perspectives in Japan (as of fall 1996). Visited 2001/05/28

Singapore

Center for Transportation Studies

http://www.ntu.edu.sg/home/cshlam/cts/centre.html

The Center for Transportation Studies (CTS) is located at the School of Civil and Structural Engineering on the Nanyang Technological University Campus. The site contains a broad description of research areas covered by the CTS. Visited 2001/05/28

TISONI (Traveller's Information ON the Internet)

http://www.ntu.edu.sg/home/cshlam/tisoni.html

Prototype consisting of three sections: public traveller's information, private traveller's information and MRT system map of singapore. Visited 2001/05/28

Traffic Scan

http://www.trafficscan.lta.gov.sg

Real-time traffic information by satellites. The site provides average speed information on roads that are frequently travelled by taxis. Visited 2001/05/28

USA

ITS America

http://www.itsa.org

Main American ITS information site. It contains news headlines about ITS in general and divided by ITS areas. The site also features a website database divided in ITS areas. Several documents and government reports are available on-line. The ITS system architecture document is available on-line

(http://www.itsa.org/architecture.html). Visited 2001/05/28

National ITS Architecture

http://www.iteris.com/itsarch

National ITS architecture presented in three views:1.The hypertext view provides immediate, interconnected access to all the elements of the architecture definition. 2.The document view

presents the complete set of architecture documentation as it exists in printed format. 3.The database view provides developers direct access to the source material for the National ITS Architecture in several connected relational databases. Visited 2001/05/29

US Department of Transportation

http://www.its.dot.gov

Contains on-line news and status reports in the different areas of ITS and a FAQ on the federal ITS program. Contains an extensive list of ITS links grouped by subject. Also fosters the site of the PIARC committee on intelligent transport (committee 16) and its library. Visited 2001/05/29

Federal Highway Administration

http://www.fhwa.dot.gov

Description of all FHWA programs and extensive list of FHWA websites, transportation websites ant other transportation resources. Features an Electronic Reading Room containing on-line reports and publications. Visited 2001/06/01

Federal Transit Authority

http://www.fta.dot.gov

Gives access to the National Transit Library containing many on-line documents (one section is dedicated to ITS). A National Transit Database is also available, containing reports and statistics. Visited 2001/05/29

University Transportation Centers

http://utc.dot.gov

The US University Transportation Centers program initiated in 1987 and reconducted in 1991 established 10 regional University Transportation centers, 4 national centers and 6 University Research institutes. This site contains links to each center and a description of their expertise area. Visited 2001/06/01

3 Digit Traveller Information Number (N11 Q&A)

http://www.its.dot.gov/comm/n11qa.htm

FAQ list about the N11 US project (old and not updated since April 1999). Visited 2001/06/01

National Transportation Library

http://ntl.bts.gov

Repository of materials from public and private organizations across United States. Many documents are on-line. A section pertains to ITS. Visited 2001/06/01

ITS Electronic Document Library

http://www.its..dot.gov/itsweb/welcome.htm

This on-line library contains a large inventory of the U.S. DOT ITS documents published since 1997. There is also a large number of documents from the 1995-1996 period. Additions will be made over time to increase the inventory of pre-1997 documents. Visited 2001/06/05

ITS-World On-line

http://www.itsworld.com

List of reference to all articles published in the ITS World magazine. A few articles are available

on-line. Also contains an extensive glossary of ITS terms and acronyms (ITS 101). Visited 2001/06/01

ITS International

http://www.itsinternational.com

List of some articles published in the ITS International magazine. Some of the articles are abridged on-line. An electronic bookshop is also available. Visited 2001/06/01

LEAP

http://www.path.berkeley.edu/~leap

LEAP - Learning from the Evaluation and Analysis of Performance. Centralized, up to date source of information on ITS tests and implementation. LEAP includes descriptions of technologies and the sites where they have been implemented, discussions of system performance and the methods used to evaluate them, benefits, capital and operating costs, problems encountered in implementation, and links to other ITS-related sites. Contents are organized according to the 30 ITS User Services defined in the USDOT's ITS Architecture. Visited 2001/06/01

PATH - Partners for Advanced Transit and Highways

http://www.path.berkeley.edu

California PATH is a joint venture of Caltrans, the University of California, Berkeley, other public and private academic institutions, and private industry, with the mission of applying advanced technology to increase highway capacity and safety and to reduce traffic congestion, air pollution, and energy consumption. The site contains short research project descriptions and several publications and research reports, many available on-line. Visited 2001/06/01

PATH database

http://www4.trb.org/trb/tris.nsf/web/path

The PATH database is a bibliographic database pertaining to ITS. It contains references to all aspects of ITS, ranging from historical materials dating back to the 1940s to topics of current interest and research. The database is bibliographic; it does not contain full-text references. URLs are given whenever possible. Visited 2001/06/01

Transportation Research Board

http://www.nas.edu/trb/

Describes the TRB organization and publications. TRB publication titles can be searched and bought on-line. Some TRB publications are available on-line. Visited 2001/06/01

TRIS

http://199.79.179.82/sundev/search.cfm

The Transportation Research Information Services (TRIS) database is a compilation of TRB and other publications on transportation research, including journal articles, technical reports, and conference proceedings. TRIS also includes descriptions of ongoing research in progress which is not yet published. Also lists other transportation databases. Has links to many other on-line transportation libraries. Visited 2001/06/01

ITS Cooperative Deployment Network

http://www.nawgits.com/icdn.html

Shared Internet resource containing up-to-date news, insight, and resources for transportation professionals and agencies alike. Many on-line articles and extensive list of ITS resources. Also contains ITS discussion forums. (Formerly itson-line) Visited 2001/06/01

Electronic Toll Collection and Traffic Management Home Page

http://www.etm.com

Contains updated news headlines, maps and tables of implemented projects in United States. Visited 2001/06/01

Intelligent Transportation Infrastructure Deployment (USDOT)

http://itsdeployment.ed.ornl.gov/iti98

Site maintaining information related to the deployment of ITS Infrastructure for the 75 largest metropolitan areas. Data current as of September 30, 1997 Visited 2001/06/01

Oak Ridge National Laboratory ITS Research Program

http://www-cta.ornl.gov/cta/research/its

Gives research project descriptions and status in four main sections: ITS Deployment Analysis System, Traffic Management Center, Dynamic Traffic Assignment and Vehicle Analysis. Also contains a list of ITS project publications. Visited 2001/06/01

Oak Ridge National Laboratory Spatial Data Interoperability Project Site

http://itsdeployment.ed.ornl.gov/spatial

Access to documents and information generated by the Oak Ridge National Laboratory (ORNL) and its subcontractors on projects aimed at producing a spatial data interoperability framework for Intelligent Transportation Systems (ITS). Documents dated 1995-1996. Visited 2001/06/01

The Intelligent Vehicle Research Program at ORNL

http://www.epm.ornl.gov/ORNL_IVI/ornl_ivi.html

One page describing the research project (august 1998). Visited 2001/06/01

University of Texas at Austin - DTA Home Page

http://www.ce.utexas.edu/prof/mahmassani/DYNASMART-X

Description of the DYNASMART-X system: concepts, interface and demo. Also contains a list of publications about the DYNASMART-X system (1995-2000). Visited 2001/06/01

Virginia Tech Center for Transportation Research - Research Center of Excellence

http://www.cte.vt.edu

Contains news and research project descriptions. Description of the Smart Road ITS evaluation research facility. Visited 2001/06/01

Texas Transportation Institute - Research Center of Excellence

http://rce.tamu.edu

Description and status reports of the research program which encompasses: Public Transportation Services, Transportation Management Services and International Border

Transportation Services/Institutional Issues. Also covers "Smart Diamond", a system to optimize the operation of a signalized diamond interchange. A Virtual Reality environment of the Smart Diamond Experiment is provided. Visited 2001/06/01

Texas Transportation Institute

http://tti.tamu.edu

Reports and on-line research summaries. List and links to TTI's national research centers and clearinghouses. Also contains an annotated list of transportation resources and links. Visited 2001/06/01

University of Michigan ITS Research Center of Excellence

http://its.engin.umich.edu/itsrce

Short description of the research priorities and projects. Visited 2001/06/01

University of Michigan Transportation Research Institute

http://www.umtri.umich.edu

Contains a searchable database of all publications by UMTRI researchers and a description of ongoing projects. Visited 2001/06/01

University of Minnesota ITS Institute at the Center for Transportation Studies

http://www.cts.umn.edu

While not formally part of the RCE centers, this research center has close links with the 3 RCEs. The sit contains a description of the research program. In addition to a small report collection, the CTS Library provides electronic access to substantial resources available in the Minnesota Department of Transportation Library and the University of Minnesota Libraries. Visited 2001/06/01

Turner Fairbanks Research Center ITS Home Page

http://www.tfhrc.gov/its/its.htm

On-line project descriptions and technical reports (many on GPS positioning). A Revised Monograph on Traffic Flow Theory is available on-line. Also contains an annotated link list of transportation related sites. Visited 2001/06/01

Advanced Rural Transportation Systems Compendium

http://www.tfhrc.gov/its/newarts.htm

On-line information system used to track ARTS projects. Contains short projects descriptions, contact and status informations. Visited 2001/06/01

ITS - University of Washington

http://www.its.washington.edu

Contains project descriptions and on-line reports. Also contains software on-line demos and realtime camera views. Highway monitoring data from the Seattle region can be queried, refined and downloaded. Every twenty seconds, a new "snapshot" of the current highway conditions is added to the database. The collection was begun on October 13,1998, and has been operating continuously since then. Visited 2001/06/01

Rural ITS

http://www.its.dot.gov/rural/rural.htm

Press releases, program plan and compendium of ARTS projects. Visited 2001/06/01

ITS for Commercial Vehicle Operation

http://www.avalon-ais.com/scvo

Joint site of FHWA and Office of Motor Carriers. Contains several CVO on-line reports. Visited 2001/06/01

National Automated Highway System Consortium (NAHSC)

http://nahsc.volpe.dot.gov

Site is closed. Contains a list of addresses and links to member of the consortium. Visited 2001/06/01

Smart Trek - Real Time Traffic Information for the Pugget Sound region

http://www.smartrek.org

Real-time traveler information (traffic updates, bus & ferry updates, customized traveler services) and trip planning (bus, ferry and trains schedules, weather, directions and yellow pages). PDA and cell phone information services are also available. Visited 2001/06/01

Automotive Multimedia Interface Collaboration

http://www.ami-c.org

Group of automobile manufacturer (Daimler-Chrysler, Ford, General Motors, Renault and Toyota) aiming to develop a set of common specifications for a multimedia interface to motor vehicle electronic systems. Site contains a few downloadable reports and version 1.0 of their interface specifications. Visited 2001/06/01

MIT ITS

http://web.mit.edu/its

Description of the DynaMIT micro-simulator project and the MITSIMLab simulation-based laboratory. Visited 2001/06/01

Transportation Information and Decision Engineering (TIDE) Center

http://www.njtide.org

Multi-university research center involving the New-Jersey Institute of Technology, Princeton University and Rutgers University. Research reports and papers available online. An extensive list of links and transportation resources on the webis also available. Visited 2001/06/01

National Transportation Library

http://www.bts.gov/ntl/subjects/its.html/

Many on-line articles and texts on ITS. Visited 2001/06/01

Canada

ITS Society of Canada
http://www.itscanada.ca
Contains a news section and an inventory of canadian ITS applications. Visited 2001/06/01

Transport Canada - Intelligent Transportation Systems
http://www.its-sti.gc.ca
General presentation, reports and publications pertaining to ITS in Canada. Visited 2001/06/01

Transport Canada - Transportation Development Center
http://www.tc.gc.ca/tdc
Contains short project descriptions, a list of publications and a list of documents available at the TDC library. Visited 2001/06/01

Canadian ITS Architecture
http://www.its-sti.gc.ca/en/architecture/static_content.htm
Details on the Canadian ITS Architecture. Visited 2001/05/25

Transportation Association of Canada
http://www.tac-atc.ca
Online databases and transportation publications, some of which pertaining to ITS. Visited 2001/06/05

Transports Québec
http://www.mtq.gouv.qc.ca/projet/projet/Act10_en.htm
Description of Research and Development ITS Projects at Transports Québec. Visited 2001/06/01

Ontario Ministry of Transportation - ITS
http://www.mto.gov.on.ca/english/its
Description of implemented ITS projects in Ontario (407 electronic toll highway, intelligent transportation border crossing system, advanced vehicle identification (CVO), COMPASS (ATMS)). Also, a traffic and road information system gives nearly continuous information about possible disruptive events on provincially maintained highways. In addition, a list of some of the world ITS live links (live road reports) is given. Visited 2001/06/01

407 Electronic Toll Highway
http://www.407etr.com
Facts and user informations about the 407 electronic toll highway. Visited 2001/06/01

University of Manitoba - Transportation Engineering
http://www.umanitoba.ca/academic_institutes/transport_institute/research
Contains many links to other transport related sites. One section contains a report describing AVCS and AVCS status in Canada (rather old 1994). The other section contains an on-line report generator giving access to traffic counts on count posts along the Manitoba highways. (As

of June 2001, numerous links on the University of Manitoba site are not working and information is rather difficult to find.) Visited 2001/06/01

University of Montreal - Transportation Research Center

http://www.crt.umontreal.ca/accueil/lab_systemes.php

Contains a description of ITS research projects and a searchable database of research reports (not available online). Visited 2001/06/01

Appendix A
User Services in American ITS Architecture

1.0	TRAVEL AND TRAFFIC MANAGEMENT
1.1	PRE-TRIP TRAVEL INFORMATION
1.1.0	ITS shall provide a Pre-Trip Travel Information (PTTI) capability to assist travelers in making mode choices, travel time estimates, and route decisions prior to trip departure. It consists of four major functions, which are, (1)Available Services Information, (2) Current Situation Information, (3) Trip Planning Service, and (4) User Access. Information is integrated from various transportation modes and presented to the user for decision making.
1.1.1	PTTI shall provide travelers with information on those travel services available for their use.
1.1.1.1	PTTI shall provide users with available services information that is timely.
1.1.1.1.1	PTTI shall provide users the latest available information on transit routes.
1.1.1.1.2	PTTI shall provide users the latest available information on transit schedules.
1.1.1.1.3	PTTI shall provide users with real time schedule adherence information.
1.1.1.1.4	PTTI shall provide users the latest available information on transit transfer options.
1.1.1.1.5	PTTI shall provide users the latest available information on transit fares.
1.1.1.1.6	PTTI shall provide users information on accessing ridematching services.
1.1.2	PTTI shall provide the capability for users to access information on the current condition of transportation systems.
1.1.2.1	PTTI transportation services current situation information shall be provided in real-time.
1.1.2.1.1	Real-time information provided by PTTI shall include the current condition of any incidents.
1.1.2.1.2	Real-time information provided by PTTI shall include the current status of any accidents or incidents.
1.1.2.1.3	Real-time information provided by PTTI shall include the current condition of any road construction.
1.1.2.1.4	Real-time information provided by PTTI shall include any currently recommended alternate routes.
1.1.2.1.5	Real-time information provided by PTTI shall include the current speeds on specific routes.
1.1.2.1.6	Real-time information provided by PTTI shall include current parking conditions in key areas.
1.1.2.1.7	Real-time information provided by PTTI shall include the schedules for any current or soon to start events.
1.1.2.1.8	Real-time information provided by PTTI shall include the current weather situation.
1.1.3	PTTI shall include a trip planning service.
1.1.3.1	PTTI trip planning service shall provide the users with information needed for planning an upcoming trip.
1.1.3.1.1	Based on user specified parameters PTTI shall provide users with a calculated itinerary.
1.1.3.1.2	Based on user specified parameters PTTI shall provide users with transportation mode choices.
1.1.3.1.3	Based on user specified parameters PTTI shall provide users with real-time travel conditions for time of inquiry and estimated conditions for estimated time of travel.
1.1.3.1.4	Based on user specified parameters PTTI shall provide users with one or more alternate itineraries in addition to the primary calculated itinerary.
1.1.3.2	PTTI shall provide the capability for users to specify those transportation parameters that are unique to their individual needs.
1.1.3.2.1	PTTI shall provide the capability for users to specify a desired destination.
1.1.3.2.2	PTTI shall provide the capability for users to specify a planned departure location.
1.1.3.2.3	PTTI shall provide the capability for users to specify their desired departure time.
1.1.3.2.4	PTTI shall provide the capability for users to specify their desired arrival time.
1.1.3.2.5	PTTI shall provide the capability for users to specify their maximum acceptable travel time.
1.1.3.2.6	PTTI shall provide the capability for users to specify their maximum acceptable number of mode changes.
1.1.3.2.7	PTTI shall provide the capability for users to specify a maximum number of transfers.
1.1.3.2.8	PTTI shall provide the capability for users to specify their preferred route(s) or segment of route(s).
1.1.3.2.9	PTTI shall provide the capability for users to specify their preferred transportation mode(s).
1.1.3.2.10	PTTI shall provide the capability for users to specify their preferred weather conditions.

1.1.3.3	In addition to the user specified parameters PTTI shall use additional factors when planning trips.
1.1.3.3.1	PTTI shall consider current travel conditions when calculating a trip itinerary.
1.1.3.3.2	PTTI shall consider predicted travel conditions when calculating a trip itinerary.
1.1.4	PTTI shall provide the capability for user access.
1.1.4.1	PTTI shall provide the capability for users to access the system from multiple distributed locations.
1.1.4.1.1	PTTI shall provide the capability for users to access the system from their homes.
1.1.4.1.2	PTTI shall provide the capability for users to access the system from their place of work.
1.1.4.1.3	PTTI shall provide the capability for users to access the system from other major trip generation sites.
1.1.4.1.4	PTTI shall provide the capability for users to access the system from personal portable devices.
1.1.4.2	PTTI shall provide the capability for users to access the system over multiple types of electronic media.
1.1.4.2.1	Access media shall comply with the American Disability Act legislation.
1.2	EN-ROUTE DRIVER INFORMATION
1.2.0	ITS shall include an En-Route Driver Information (DI) function. Driver Information provides vehicle drivers with information, while en-route, which will allow alternative routes to be chosen for their destination. Driver Information consists of two major functions which are (1) Driver Advisory and (2) In-vehicle Signing. The potential decrease in traffic may also provide benefits in highway safety, reduced air pollution, and decreased congestion.
1.2.1	DI shall include the following general requirements.
1.2.1.1	DI shall be implemented in a manner that helps improve highway safety.
1.2.1.2	DI shall be implemented in a manner that helps reduce air pollution.
1.2.1.3	DI shall be implemented in a manner that helps decrease congestion.
1.2.1.4	DI shall be designed in a manner that permits a two-phase implementation.
1.2.1.4.1	The DI two-phase implementation shall include a short term capability to address those features that can be implemented in the present time frame.
1.2.1.4.2	The DI two-phase implementation shall include a long term capability to address those features that can be implemented when the remainder of the ITS system is deployed.
1.2.1.5	DI shall include a driver advisory capability and an in-vehicle signing capability.
1.2.2	Driver advisory shall be implemented in two phases with first a short term capability and later a long term capability.
1.2.2.1	The short term DI driver information capability shall include the ability to provide information to travelers within the limited area of deployment.
1.2.2.1.1	DI shall include the capability to provide travelers with accurate information concerning available travel options and their state of operational availability.
1.2.2.1.2	DI shall provide that information to travelers required for them to avoid areas of congestion.
1.2.2.1.2.1	DI shall provide that information needed for travelers to select those transportation modes that allow them to avoid congestion.
1.2.2.1.3	DI shall provide the capability for users to receive travel information in their vehicles.
1.2.2.1.4	In the short-term DI shall be deployed in those limited areas where the need and associated benefits are more immediate.
1.2.2.2	The long term DI driver information capability shall include the ability to provide information to travelers within all geographic areas of the ITS deployment.
1.2.3	DI shall provide an in-vehicle signing capability.
1.2.3.1	The DI in-vehicle signing function shall include a short term capability to serve the more immediate needs of travelers.
1.2.3.1.1	The short term in-vehicle signing function shall include the capability to provide assistance to individuals with impaired vision.
1.2.3.1.2	The short term in-vehicle signing function shall include the capability to provide assistance to individuals needing local guidance in areas that the driver is unfamiliar with (e.g., airports, resort areas).
1.2.3.1.3	The short term in-vehicle signing function shall include the capability to provide assistance to individuals in areas that frequently have conditions of poor visibility.
1.2.3.1.4	The short term in-vehicle signing function shall be implemented in a manner that augments existing signs.

1.2.3.1.4.1	The short term in-vehicle signing function shall augment control signs (e.g., stop signs).
1.2.3.1.4.2	The short term in-vehicle signing function shall augment warning signs (e.g., slow signs).
1.2.3.1.5	The short term in-vehicle signing function shall provide a user interface that allows travelers to access its capabilities.
1.2.3.2	The DI in-vehicle signing function shall include a long term capability to serve more of the traveler's needs.
1.2.3.2.1	The long term in-vehicle signing function shall be integrated with other ITS system capabilities.
1.2.3.2.2	The long term in-vehicle signing function shall provide the capability to customize warnings.
1.2.3.2.2.1	The customized warnings function shall provide the capability to control the contents of warning messages to the extant environmental conditions.
1.2.3.2.3	The in-vehicle signing function shall provide the capability to utilize data from roadside environmental sensors as inputs to warning messages.
1.2.3.2.4	The in-vehicle signing function shall provide travelers with information on road conditions.
1.2.3.2.5	The in-vehicle signing function shall provide travelers with precautionary reminder messages.
1.3	ROUTE GUIDANCE
1.3.0	ITS shall include a Route Guidance (RG) function. Route Guidance will provide travelers with directions to selected destinations. Four functions are provided which are (1) Provide Directions, (2) Static Mode, (3) Real-Time Mode, and (4) User Interface.
1.3.1	RG shall include the capability to Provide Directions to travelers.
1.3.1.1	The Provide Directions function shall provide travelers with directions to their selected destination locations.
1.3.1.2	The Provide Directions function shall issue directions to travelers that is based on information about current conditions of transportation systems.
1.3.1.2.1	Current transportation system conditions upon which directions to travelers is based shall include, but not be limited to, the following:
1.3.1.2.1(a)	Current traffic conditions.
1.3.1.2.1(b)	Status of transit systems.
1.3.1.2.1(c)	Schedules of transit systems.
1.3.1.2.1(d)	Events taking place that influence travel routes.
1.3.1.2.1(d).1	Street closures.
1.3.1.2.1(d).2	Pedestrian events.
1.3.1.2.1(d).3	No pedestrian zones.
1.3.1.3	The Provide Direction function shall issue traveler directions that are simple and easy to understand in the form of arrow displays or voice messages providing turning instructions of which way to turn onto including, but not limited to, the following:
1.3.1.3(a)	Particular streets.
1.3.1.3(b)	Roads.
1.3.1.3(c)	Walkways.
1.3.1.3(d)	Transit facilities.
1.3.2	RG shall include a Static Mode for issuing information to travelers.
1.3.2.1	Static Mode shall provide travelers with information that includes, but is not limited to, the following:
1.3.2.1(a)	Mapping information about roadways.
1.3.2.1(b)	Scheduling information about transit systems.
1.3.2.2	Static Mode infrastructure systems shall provide the capability to have two-way communications between the traveler and the infrastructure.
1.3.2.2.1	The two-way communications shall provide the capability for the infrastructure to receive the traveler's desired destination.
1.3.2.2.2	The two-way communications shall provide the capability to provide directions back to the traveler that are based on the infrastructure's calculated routing.
1.3.2.3	The Real-Time Mode shall provide the capability for autonomous operation of mobile based systems.
1.3.2.3.1	Autonomous Mobile Based systems shall have the capability to operate independent of infrastructure.
1.3.3	RG shall include a Real-Time Mode for issuing information to travelers.

1.3.3.1	The Real-Time Mode shall utilize current travel condition information to provide performance that is enhanced over the Static Mode performance, to include, but not be limited to, the following:
1.3.3.1(a)	Traffic conditions information.
1.3.3.1(b)	Dynamic transit schedule information.
1.3.3.2	The Real-Time Mode shall include the capability to operate in either or both of the following two configurations:
1.3.3.2(a)	Route selection processors located on the mobile unit.
1.3.3.2(b)	Route selection processors installed in the transportation system infrastructure.
1.3.3.2.1	Real-Time Mobile Based systems shall include the capability to receive infrastructure information, when available, and use it in determining routing.
1.3.3.2.2	If current real-time information is included in route determination the system shall be denoted as an Infrastructure-based real-time system.
1.3.3.3	The Real-Time mode shall provide the capability for autonomous operation of mobile-based systems.
1.3.4	RG shall include a User Interface function.
1.3.4.1	The User Interface shall provide the capability for travelers to access the system by utilizing interactive devices that include, but are not limited to, the following:
1.3.4.1(a)	Visual displays.
1.3.4.1(b)	Keypads.
1.3.4.1(c)	Touch sensitive devices.
1.3.4.1(d)	Computer generated voice.
1.3.4.1(e)	Voice recognition system.
1.3.4.2	Mobile systems shall use the best information available to provide routing instructions.
1.3.4.2.1	Mobile Systems shall provide the capability for individual travelers to customize the routing selected for them.
1.3.4.2.2	Mobile Systems customizing of traveler's routing shall be based on certain conditions specified by the traveler to include, but not be limited to, the following:
1.3.4.2.2(a)	Avoid expressway-type highways.
1.3.4.2.2(b)	Avoid multiple mass transit transfers.
1.3.4.3	Infrastructure-based systems shall also permit individual travelers to customize their routing selection.
1.3.4.3.1	Infrastructure-based systems shall use the traveler's destination information to estimate extra demand on the transportation system and then provide routing to the traveler based on this predicted demand.
1.4	RIDE MATCHING AND RESERVATION
1.4.0	ITS shall include a Ride Matching and Reservation (RMR) function. Ride Matching and Reservation will provide travel users with information on rideshare providers. Three major functions are provided which are (1) Rider Request, (2) Transportation Provider Services, and (3) Information Processing. This will also include a billing service to the providers.
1.4.1	RMR shall include a Rider Request capability.
1.4.1.1	Rider Request shall provide the capability for a traveler to request a ride by placing a single request from a facility to include, but not be limited to, the following:
1.4.1.1(a)	Telephones (including hearing-impaired capability).
1.4.1.1(b)	Kiosks.
1.4.1.2	Rider Request shall provide a traveler the capability to request a specific itinerary by specifying, but not be limited to, the following:
1.4.1.2(a)	Date.
1.4.1.2(b)	Time of pick-up and drop-off.
1.4.1.2(c)	Origin.
1.4.1.2(d)	Destination.
1.4.1.2(e)	Specific restrictions or preferences.
1.4.1.3	Based on the traveler's request and specified itinerary, Rider Request shall provide the traveler with the available ridesharing options.
1.4.1.4	Rider Request shall also include the capability to perform real-time ridematching by instantly matching rider and driver.
1.4.2	RMR shall include an Transportation Provider Service function.

1.4.2.1	Transportation Provider Services shall include the capability for providers to have their billing arranged through a central clearinghouse.
1.4.2.2	Transportation Provider Services shall include electronic safeguards against fraud and abuse.
1.4.2.3	Transportation Provider Services shall automatically generate needed reports and financial documentation.
1.4.2.4	Transportation Provider Services shall include the capability for commercial operators such as van pools and taxis to be included as options for requesting travelers.
1.4.3	RMR shall include an Information Processing function.
1.4.3.1	Information Processing shall quickly match preferences and demands of requesting travelers with the services available from providers.
1.4.3.2	Information Processing shall provide a clearinghouse capability for rideshare financial transactions.
1.4.3.3	Information Processing shall link together the services available from all travel modes including, but not limited to, the following:
1.4.3.3(a)	Bus.
1.4.3.3(b)	Rail.
1.4.3.3(c)	Vanpools.
1.4.4.3(d)	Express bus.
1.4.4.3(e)	Commercial providers.
1.4.4.3(f)	Specialized service.
1.4.4.3(g)	Carpools.
1.4.3.4	Information Processing shall provide the informational infrastructure needed to connect providers and consumers.
1.4.3.5	Information Processing shall provide the capability to gather that market information needed to assist in the planning of service improvements.
1.4.3.6	Information Processing shall provide the capability to gather that market information needed to assist in maintenance of operations.
1.5	TRAVELER SERVICES INFORMATION
1.5.0	ITS shall include a Traveler Services Information (TSI) function. Traveler Services Information provides travelers with service and facility data for the purpose of assisting prior to embarking on a trip or after the traveler is underway. The functions which are included in this capability are Information Receipt and Information Access. This will provide the traveler with a "yellow pages" type of capability.
1.5.1	TSI shall include an Information Receipt function for the collection of that information provided to travelers.
1.5.1.1	Information Receipt shall provide and maintain a database of local area services available to travelers.
1.5.1.2	Information Receipt provides the capability to acquire up to the minute information relating to traveler services available in the local area.
1.5.1.2.1	Information Receipt shall acquire information on the condition of local traveler services.
1.5.1.2.2	Information Receipt shall acquire information on the status of local traveler services.
1.5.1.2.3	Information Receipt shall acquire information on the availability of local traveler services.
1.5.1.2.4	Information Receipt shall acquire information on the availability of local motorist services.
1.5.1.2.5	Information Receipt shall acquire information on the availability of local tourist services.
1.5.1.3	Information Receipt shall be capable of being integrated with Pre-Trip Planning information.
1.5.1.4	Information Receipt shall provide the capability to support those financial transactions required for travelers to be billed for the purchase of activity tickets and room reservations.
1.5.1.5	Information Receipt shall include the capability to have interactive connectivity between users, sponsors and providers of services.
1.5.2	TSI shall include an Information Access function that allows travelers to access the available information.
1.5.2.1	Information Access shall provide the capability for travelers to request and receive general information about the local area.
1.5.2.2	Information Access shall provide the capability for travelers to request and receive information about specific services in an area to include but, not be limited to, the following:
1.5.2.2(a)	Lodging information.

1.5.2.2(b)	Food information.
1.5.2.2(c)	Parking information.
1.5.2.2(d)	Hours of operation information.
1.5.2.2(e)	Tourist activities information.
1.5.2.2(f)	Daily or special events information.
1.5.2.2(g)	Local hospital information.
1.5.2.2(h)	Nearest gas station information.
1.5.2.3	Information Access shall provide the capability for travelers to request specific actions of area service providers to include, but not be limited to:
1.5.2.3(a)	Lodging reservations.
1.5.2.3(b)	Dining reservations.
1.5.2.4	Information Access shall provide the capability for all travelers to access information regardless of their particular mode of travel.
1.5.2.5	Information Access shall provide the capability for travelers to access the TSI information via any of, but not limited to, the following methods:
1.5.2.5(a)	Highway advisory radio.
1.5.2.5(b)	Dial-up telephone lines.
1.5.2.5(c)	Computers at home.
1.5.2.5(d)	Computers in the office.
1.5.2.5(e)	In-vehicle computers.
1.5.2.5(f)	Public area kiosks.
1.5.2.5(g)	Personal portable devices.
1.5.2.6	Information Access shall provide the capability for travelers to access TSI information from public kiosk locations which include, but are not limited to:
1.5.2.6(a)	Rest areas.
1.5.2.6(b)	Activity centers.
1.5.2.6(c)	Tourist attractions.
1.5.2.6(d)	Service plazas.
1.5.2.6(e)	Airports.
1.6	TRAFFIC CONTROL
1.6.0	ITS shall provide a Traffic Control capability. Traffic Control provides the capability to efficiently manage the movement of traffic on streets and highways. Four functions are provided which are (1) Traffic Flow Optimization, (2) Traffic Surveillance, (3) Control Function, and (4) Provide Information. This will also include control of network signal systems with eventual integration of freeway control.
1.6.1	Traffic Control shall include a Flow Optimize function to provide the capability to optimize traffic flow.
1.6.1.1	The Flow Optimize function shall employ control strategies that seek to maximize traffic-movement efficiency.
1.6.1.1.1	Traffic-movement control shall manage movement of traffic on streets.
1.6.1.1.2	Traffic-movement control shall manage movement of traffic on highways.
1.6.1.1.3	Traffic-movement control shall include the goal of minimizing delay times.
1.6.1.1.4	Traffic-movement control shall include the goal of minimizing energy use.
1.6.1.1.5	Traffic-movement control shall include the goal of minimizing air quality impacts due to traffic.
1.6.1.2	The Flow Optimize function shall include a Wide Area optimization capability, to include several jurisdictions.
1.6.1.2.1	Wide area optimization shall integrate the control of network signal systems with the control of freeways.
1.6.1.2.2	Wide area optimization shall include features that provide preferential treatment for transit vehicles.
1.6.1.2.3	Wide area optimization shall include features that provide preferential treatment for HOV.
1.6.1.3	Flow optimize shall be implemented in a manner that seeks to optimize traffic movement over a large geographic area.
1.6.1.4	Flow optimize shall include a Control function that is responsive to both the current demand as well as the expected demand.
1.6.1.4.1	Control shall include the capability to facilitate the dissipation of traffic congestion.

1.6.1.5	Flow Optimize shall provide the capability to predict travel patterns.
1.6.1.6	The Control Function shall include the use of data acquired from traffic surveillance as feedback to the control strategies.
1.6.1.7	Implementation of the Control Function shall include strategies that account for at least the following:
1.6.1.7(a)	Human factors.
1.6.1.7(b)	Driver/traveler behavior and expectancies.
1.6.2	Traffic Control shall include a Traffic Surveillance function.
1.6.2.1	Traffic Surveillance shall include a Vehicle Detection function with the capability of accurately detecting vehicles ina real-time fashion.
1.6.2.1.1	Vehicle Detection shall include the capability to determine those vehicles that are HOVs.
1.6.2.2	Traffic Surveillance shall include a Data Collect function to provide the capability to collect data that are needed for determining traffic flow and prediction.
1.6.2.2.1	Data Collect shall provide the capability to quickly feedback traffic data to the control processes.
1.6.2.3	Traffic Surveillance shall include an area wide surveillance capability to include several jurisdictions.
1.6.2.3.1	The area wide surveillance shall gather speed and flow information.
1.6.2.3.2	The area wide surveillance shall cover a large number of roadway segments.
1.6.2.4	Traffic Control shall provide the capability to acquire detailed traffic measurements at specific locations.
1.6.2.4.1	Traffic Surveillance shall include a Data Process function to process the traffic data which are acquired.
1.6.2.5	The wide area surveillance shall acquire sufficient data to provide the system with the knowledge of the existing conditions.
1.6.2.5.1	Data Process shall combine and process traffic data from multiple sources and times in order to improve the accuracy of the view of the current traffic condition.
1.6.2.5.2	Data Process shall process traffic data to generate near term predictions of traffic conditions.
1.6.3	Traffic Control shall include a Control Function.
1.6.3.1	The Device Control Function shall include a "real-time" traffic-adaptive control capability.
1.6.3.2	The real-time traffic-adaptive control portion of the Control Function shall be an area wide control to include several jurisdictions.
1.6.3.2.1	The area wide control shall be implemented in an integrated and consistent manner that avoids the issuance of conflicting controls.
1.6.3.2.2	The area wide control shall be implemented in a manner that permits the following types of vehicles to have preference over other vehicles being controlled.
1.6.3.2.2(a)	Transit.
1.6.3.2.2(b)	HOV.
1.6.3.2.2(c)	Emergency Medical Service Vehicles.
1.6.3.3	The Device Control Function shall provide the capability to exercise control over those devices utilized for traffic control.
1.6.3.3.1	Device Control shall include the capability to control traffic signalization, including rapid modification of signalization parameters to respond to traffic requirements.
1.6.3.3.2	Device Control shall include the capability to control dynamically traffic signing.
1.6.3.3.3	Device Control shall include the capability to control freeway ramp metering.
1.6.3.3.4	Device Control shall include the capability to exercise dynamic control over the infrastructure (such as reversible-lanes, turning restrictions, etc.).
1.6.3.4	Device Control shall communicate control data to the following devices.
1.6.3.4(a)	Traffic signals.
1.6.3.4(b)	Ramp meters.
1.6.3.4(c)	Information signs.
1.6.3.4(d)	HOV lanes.
1.6.3.4(e)	Human operator support.
1.6.3.4.1	Traffic Surveillance shall include a Data Process function to process the traffic data which are acquired.
1.6.3.5	Device Control shall provide the operator with the capability to manually override the system's automatic controls.

1.6.3.6	Device Control shall provide the operator the capability to adaptively change system response in order to provide a coordinated support of other TMCs that are responding to incidents.
1.6.4	The Control Function shall provide traffic control information to other elements of the ITS, including but not limited to the following:
1.6.4(a)	In-vehicle navigation.
1.6.4(b)	Trip planning.
1.6.4(c)	Routing systems.
1.6.4(d)	Fleet management systems.
1.7	INCIDENT MANAGEMENT
1.7.0	ITS shall include an Incident Management (IM) function. Incident Management will identify incidents, formulate response actions, and support initiation and ongoing coordination of those response actions. Six major functions are provided which are (1) Scheduled Planned Incidents, (2) Identify Incidents, (3) Formulate response Actions, (4)Support Coordinated Implementation of Response Actions, (5) Support Initialization of Response to Actions, and (6) Predict Hazardous Conditions.
1.7.1	Incident Management shall provide an incident identification function to identify incidents.
1.7.1.1	The incident identification function shall include the capability to identify predicted incidents.
1.7.1.1.1	The incident identification function shall use information from the following types of sources, where available, to identify predicted incidents:
1.7.1.1.1(a)	Traffic flow sensors.
1.7.1.1.1(b)	Environmental sensors.
1.7.1.1.1(c)	Public safety sources.
1.7.1.1.1(d)	Media sources.
1.7.1.1.1(e)	Weather information sources.
1.7.1.1.1(f)	Transportation providers.
1.7.1.1.1(g)	Sponsors of special events.
1.7.1.1.1(h)	Hazardous condition prediction algorithms.
1.7.1.1.2	The incident identification function shall determine at least the following characteristics of each predicted incident:
1.7.1.1.2(a)	Type.
1.7.1.1.2(b)	Extent.
1.7.1.1.2(c)	Severity.
1.7.1.1.2(d)	Location.
1.7.1.1.2(e)	Expected duration.
1.7.1.1.3	The incident identification function shall determine the expected traffic flow impact of each predicted incident.
1.7.1.2	The incident identification function shall include the capability to identify existing (both planned and unplanned) incidents.
1.7.1.2.1	The incident identification function shall use information from the following types of sources, where available, to identify existing incidents:
1.7.1.2.1(a)	Traffic flow sensors.
1.7.1.2.1(b)	Environmental sensors.
1.7.1.2.1(c)	Public safety sources.
1.7.1.2.1(d)	Media sources.
1.7.1.2.1(e)	Weather information sources.
1.7.1.2.1(f)	Transportation providers.
1.7.1.2.1(g)	Travelers.
1.7.1.2.2	The incident identification function shall determine and continuously monitor at least the following characteristics of each existing incident:
1.7.1.2.2(a)	Type.
1.7.1.2.2(b)	Extent.
1.7.1.2.2(c)	Severity.
1.7.1.2.2(d)	Location.
1.7.1.2.2(e)	Expected duration.
1.7.1.2.3	The incident identification function shall determine and continuously monitor the current and expected traffic flow impact of each existing incident.

1.7.2	Incident Management shall provide a response formulation function to formulate appropriate response actions to each identified incident and revise those actions when necessary.
1.7.2.1	The response formulation function shall propose and facilitate the appropriate scheduling of those predicted incidents that can be scheduled to minimize incident potential, incident impacts, and/or the resources required for incident management.
1.7.2.2	The response formulation function shall propose and facilitate the appropriate dispatch of emergency response vehicles to an incident.
1.7.2.3	The response formulation function shall propose and facilitate the appropriate dispatch of service vehicles to an incident.
1.7.2.4	The response formulation function shall propose and facilitate the appropriate dissemination of incident related information to travelers and potential travelers.
1.7.2.5	The response formulation function shall propose and facilitate the appropriate control of traffic signals and other traffic control to reduce the traffic flow impact of an incident.
1.7.3	Incident Management shall include a response implementation function to provide those services needed to implement a coordinated incident response using all appropriate agencies.
1.7.3.1	The response implementation function shall provide at least the following decision support capabilities needed to implement coordinated incident response actions by all participating institutions:
1.7.3.1(a)	Response implementation shall allow coordinated selection/determination of the procedures needed for resolution of each incident and provide the procedures to those agencies responding to the incident.
1.7.3.1(b)	Response implementation shall provide the status of all resources needed for incident resolution to those agencies responding to the incident.
1.7.3.2	The response implementation function shall provide a link between Incident Management and all other user services necessary to implement incident response actions.
1.7.3.3	The response implementation function shall provide the capability to disseminate information relating to response status to other agencies and user services.
1.7.4	Incident Management shall provide the capability to predict the time and location of hazardous conditions that may cause an incident.
1.8	TRAVEL DEMAND MANAGEMENT
1.8.0	Travel Demand Management will generate and communicate management and control strategies that will support and facilitate the implementation of TDM programs, policies and regulations. It consists of two major functions which are (1) Increase Efficiency of Transportation System and (2) Provide Wide Variety of Mobility Options.
1.8.1	TDM shall include a communications function.
1.8.1.1	The communications function shall include the capability to send the information needed to implement management and control strategies that are in response to policies and regulations.
1.8.1.2	The communications function shall include the capability to send information and rates needed to implement management and control strategies that respond to changing environments, conditions, and policy needs to include, but not limited to, the following locations of action:
1.8.1.2(a)	Parking facilities.
1.8.1.2(b)	HOV lanes.
1.8.1.2(c)	Transit centers.
1.8.1.2(d)	Employment sites.
1.8.1.2(e)	Toll facilities.
1.8.1.2(f)	Travel (and traveler) information facilities.
1.8.1.2(g)	Ridesharing facilities.
1.8.1.3	TDM shall provide the capability to receive information and rates needed to implement management and control strategies that respond to changing environments, conditions, and policy needs to include, but not limited to, the following locations of action:
1.8.1.3(a)	Parking facilities.
1.8.1.3(b)	HOV lanes.
1.8.1.3(c)	Transit centers.
1.8.1.3(d)	Employment sites.
1.8.1.3(e)	Toll facilities.
1.8.1.3(f)	Travel (and traveler) information facilities.

1.8.1.3(g)	Ridesharing facilities.
1.8.1.4	The communications function shall provide the capability to send information and data is needed to implement management and control strategies that respond to changing environments, conditions, and policy needs to include, but not limited to, the following:
1.8.1.4(a)	Sensor data.
1.8.1.4(b)	Individual vehicle monitoring.
1.8.1.4(c)	Parking availability.
1.8.1.4(d)	Usage data.
1.8.1.5	The communications function shall provide the capability to receive information and data from transportation operators and/or users that delineates their:
1.8.1.5(a)	Current status.
1.8.1.5(b)	Needs.
1.8.1.5(c)	Level of activity.
1.8.1.6	The communications function shall include the capability for two-way communications with other ITS user services including, but not limited to, the following:
1.8.1.6(a)	Pre-Trip Planning.
1.8.1.6(b)	En-Route Transit Advisory.
1.8.1.6(c)	Driver Information.
1.8.1.6(d)	Ride Matching and Reservation.
1.8.1.6(e)	Electronic Payment.
1.8.1.6(f)	Traffic Control.
1.8.2	TDM shall include a processing function.
1.8.2.1	The processing function shall provide the capability to generate management and control strategies that facilitate the implementation of policies and regulations designed to address the following:
1.8.2.1(a)	Vehicle trip reduction.
1.8.2.1(b)	HOV lanes and ramps.
1.8.2.1(c)	Parking management and control.
1.8.2.1(d)	Ridesharing and transit.
1.8.2.1(e)	Air pollution/emission information and detection.
1.8.2.1(f)	Public awareness of travel alternatives.
1.8.2.2	The processing function shall provide those capabilities needed to enhance the ability to implement and enforce the following:
1.8.2.2(a)	Federal policies.
1.8.2.2(b)	State policies.
1.8.2.2(c)	Local Policies.
1.8.2.3	Strategies developed by the processing function shall include the guidance for the operation of physical systems that:
1.8.2.3(a)	Monitor traffic.
1.8.2.3(b)	Inform travelers.
1.8.2.3(c)	Collect fees.
1.8.2.3(d)	Detect traffic.
1.8.2.4	The processing shall provide the capability generate guidance for the pricing and control for locations of action that include, but are not limited to, the following:
1.8.2.4(a)	Parking facilities.
1.8.2.4(b)	HOV lanes.
1.8.2.4(c)	Transit centers.
1.8.2.4(d)	Employment sites.
1.8.2.4(e)	Toll facilities.
1.8.2.4(f)	Travel information facilities.
1.8.2.4(g)	Ridesharing facilities.
1.8.2.5	The processing shall provide the capability to develop strategies for implementation of policies and regulations that will accommodate the following:
1.8.2.5(a)	Public sector users and service providers.
1.8.2.5(b)	Private sector users and service providers.
1.8.2.5(c)	Issues of legality.

1.8.2.5(d)	Privacy act.
1.8.2.5(e)	Multi-jurisdictional settings.
1.8.2.6	The processing function shall provide the capability to generate management and control strategies that dynamically respond to changing environments, conditions, and policies.
1.8.2.7	The processing function's dynamically generated management and control strategies shall include the control of HOV facilities including, but not limited to, the following:
1.8.2.7(a)	Lanes.
1.8.2.7(b)	Ramps.
1.8.2.7(c)	Parking areas.
1.8.2.8	The processing function's generation of management and control strategies for HOV facilities shall include as factors, but not be limited to, the following:
1.8.2.8(a)	Auto occupancy requirements.
1.8.2.8(b)	Priority for selected vehicle types at ramps.
1.8.2.8(c)	Priority for selected vehicle types at signalized intersections.
1.8.2.9	The processing function's dynamically generated management and control strategies shall include those roadway pricings that respond to the need for congestion control to include, but not be limited to, the following:
1.8.2.9(a)	Road user and toll rates.
1.8.2.9(b)	Transit fares adjusted concomitant with tolls.
1.8.2.9(c)	Time of day usage pricing (i.e. off hour rates).
1.8.2.10	The processing function's dynamically generated management and control strategies shall include the parking management and controls to include, but not be limited to, the following:
1.8.2.10(a)	Price structure.
1.8.2.10(b)	Allocation to selected vehicles.
1.8.2.10(c)	Variable message signs.
1.8.2.11	The processing function's dynamically generated management and control strategies for parking management and controls shall be based on factors that include, but are not limited to, the following:
1.8.2.11(a)	Parking availability.
1.8.2.11(b)	Usage data.
1.8.2.12	The processing function's dynamically generated management and control strategies shall include the capability to respond to the need for control of pollution by generating messages for variable signs that include, but are not limited to, the following:
1.8.2.12(a)	Informing of higher tolls.
1.8.2.12(b)	Informing of higher parking fees.
1.8.2.13	The processing function's dynamically generated management and control strategies for air pollution control shall be based on factors that include, but are not limited to, the following:
1.8.2.13(a)	Sensor data.
1.8.2.13(b)	Individual vehicle monitoring.
1.8.2.13(c)	Individual vehicles database files.
1.8.2.14	The processing function's dynamically generated management and control strategies shall include the capability to respond to the need for the travelers to change modes by generating messages for variable signs that include, but are not limited to, the following:
1.8.2.14(a)	Where the mode change requests are being made.
1.8.2.14(b)	How the mode changes are requested to be made.
1.8.2.14(c)	Why the mode changes are requested to be made.
1.8.3	TDM shall include a sensors/control function.
1.8.3.1	The sensors/control function shall provide the capability to gather information needed for the generation of management and control strategies to include, but not be limited to the, following:
1.8.3.1(a)	Parking availability.
1.8.3.1(b)	Usage levels.
1.8.3.1(c)	Vehicle occupancy.
1.8.3.1(d)	Vehicle pollution levels.
1.9	EMISSIONS TESTING AND MITIGATION
1.9.0	ITS shall include an Emission Testing and Mitigation (ETAM) Function. The ETAM function will provide state and local governments with the capability to enhance their air quality control

strategies. The ETAM will provide both wide area and roadside emissions monitoring. Information gleaned from ETAM will be used by Traffic Demand Management (TDM) in the Traffic Management Center (TMC) to mitigate pollution and may be provided to enforcement agencies to compel offenders to comply with standards.

1.9.1 ETAM shall include a Wide Area Pollution Monitoring (WAPM) capability.

1.9.1.1 WAPM shall support air quality control strategies by assessing the level of emission of ozone precursors in all sectors of the area.

1.9.1.1.1 WAPM shall be capable of detecting the level of emission of ozone precursors with a high degree of accuracy.

1.9.1.1.2 WAPM shall be capable of determining those sectors, within its monitored area, whose emissions exceed the emission standard.

1.9.1.1.3 WAPM shall be capable of automatic self-calibration.

1.9.1.2 WAPM shall be capable of providing air quality statistical data to the TMC.

1.9.1.2.1 WAPM shall be capable of providing the air quality data on the monitored values of pollution.

1.9.1.2.2 WAPM shall be capable of providing the necessary data on emission standards violators for enforcement of air quality standards.

1.9.2 ETAM shall include roadside pollution assessment (RPA) capabilities.

1.9.2.1 RPA shall be capable of detecting the level of emission of ozone precursors with a high degree of accuracy.

1.9.2.1.1 RPA shall be capable of detecting moving vehicles, within its monitored area, whose emissions violate the emission standard.

1.9.2.1.2 RPA shall be capable of automatic self-calibration.

1.9.2.1.3 RPA shall be capable of reading suitable equipped vehicle's diagnostic data to determine that vehicle's operational status.

1.9.2.1.4 RPA shall be capable of determining suspected vehicle's registration data either by license plate or via automatic vehicle identification.

1.9.2.1.5 RPA shall be capable of determining which suspected vehicles are not in compliance with emission standards for that vehicle from the vehicle's registration data.

1.9.2.2 RPA shall be capable of providing air quality statistical data to the TMC.

1.9.2.2.1 RPA shall be capable of providing the air quality data on the monitored values of pollution.

1.9.2.2.2 RPA shall be capable of providing the necessary data to alert non-complaint vehicle drivers of their violation via roadside message signs or in-vehicle devices.

1.9.2.2.3 RPA shall be capable of providing the necessary data on violating vehicles for enforcement of air quality standards.

1.10 Highway-Rail Intersection

1.10.1 The Highway-Rail Intersection (HRI) shall be applicable to operational, at-grade highway-rail intersections with train operational speeds up to 125 MPH.

1.10.1.1 HRI users shall include light rail transit and rapid rail transit approaching and crossing HRIs.

1.10.1.2 HRI users shall include commuter rail trains approaching and crossing HRIs.

1.10.1.3 HRI users shall include freight and intercity passenger trains approaching and crossing HRIs.

1.10.1.4 HRI users shall include highway vehicles approaching and crossing HRIs.

1.10.1.5 HRI users shall include motor vehicle operators, bicyclists and pedestrians approaching and crossing HRIs.

1.10.1.6 HRI users shall include train crews operating rail traffic while approaching and crossing HRIs.

1.10.1.7 HRI users shall include rail maintenance and inspection vehicles approaching and crossing HRIs.

1.10.2 HRI shall provide interfaces between highway and rail management functions.

1.10.2.1 HRI shall provide information management interfaces between highway and rail to coordinate traffic, demand and schedules.

1.10.2.1.1 HRI shall be capable of acquiring current train schedules from rail operations functions, and shall determine projected HRI closure times and duration.

1.10.2.1.2 HRI shall be capable of interacting with traffic management functions.

1.10.2.1.3 HRI shall provide closure data to traffic management for in-vehicle traveler advisory messages.

1.10.2.2 HRI shall provide the capability for interactive real-time interfaces.

1.10.2.2.1 HRI shall provide the capability to interface with rail operations functions for rail traffic control information.

1.10.2.2.2	HRI shall provide the capability to interface with traffic management functions for highway traffic coordination.
1.10.2.2.3	HRI shall provide the capability interface with trains approaching and crossing the HRI for traffic coordination.
1.10.2.2.4	HRI shall provide the capability interface with highway vehicles approaching and crossing HRIs for traffic control information.
1.10.3	At all HRIs with active railroad warning systems, HRI shall manage the traffic in the intersection.
1.10.3.1	HRI shall be capable of augmenting the intersection with standard highway traffic signal devices.
1.10.3.2	HRI shall include an automated collision avoidance function for highway vehicles approaching HRIs.
1.10.3.3	HRI shall provide an Intelligent Intersection Controller (IIC) function to manage highway and rail traffic in the intersection.
1.10.3.3.1	IIC shall control active highway traffic signal devices at HRIs to manage highway traffic.
1.10.3.3.2	IIC function shall control active railway warning devices, including flashing lights and physical barriers for highway and walkway lanes at HRIs.
1.10.3.3.3	IIC function shall provide an intersection surveillance system to derive the real-time status of traffic in the intersection.
1.10.3.3.4	IIC function shall report real-time HRI equipment status.
1.10.3.3.5	IIC function shall report real-time HRI traffic status as advisories or alerts.
1.10.4	HRI shall include a Standard Speed Rail (SSR) Subservice to manage highway and rail traffic at HRIs for rail lines with operational speeds less than 80 MPH.
1.10.4.1	SSR shall include active railroad warning systems at designated HRIs.
1.10.4.2	SSR shall include passive HRIs with non-active warning systems.
1.10.4.2.1	SSR shall augment passive warning signs with additional highway traffic control devices at passive HRIs.
1.10.5	HRI shall provide a High Speed Rail (HSR) Subservice for HRIs on rail lines with operational speeds between 80and 125 MPH.
1.10.5.1	HSR shall include active roadside message devices to provide highway closure information at HSR HRIs.
1.10.5.2	HSR shall provide special safety features to enhance safety.
1.10.5.2.1	HSR shall close the HRI to highway traffic at a predetermined time (up to three minutes) before train arrival or when directed by train operations.
1.10.5.2.2	HSR shall include a positive barrier function (e.g. four quadrant gates) to close the intersection to highway traffic for rail lines operating at speeds over 110 MPH.
1.10.5.2.3	HSR HRIs shall verify the intersections status as either "OPEN" or "BLOCKED" for rail traffic by an immobile obstacle.
1.10.5.2.4	HSR shall provide HRI status to rail operations functions as either a "PROCEED": or "STOP" indication.
1.10.5.2.5	HSR shall provide HRI status to the train as either a "PROCEED": or "STOP" indication.
1.10.5.2.6	HSR shall provide HRI status to highway vehicles as either a "STOP FOR TRAIN" or "PROCEED" indication.
1.10.6	At HRIs with active railroad warning systems, HRI shall provide the capability for automatic collision notification to rail operations and traffic management.
2.0	PUBLIC TRANSPORTATION MANAGEMENT
2.1	PUBLIC TRANSPORTATION MANAGEMENT
2.1.0	ITS shall include a Public Transportation Management (PTM) function.
2.1.1	PTM shall include an Operation of Vehicles and Facilities (OVF) function that provides computer assisted control of the operation of vehicles and their associated facilities.
2.1.1.1	To enable the automation of the vehicle and facilities operations OVF shall provide the capability to gather the needed data to include, but not be limited to, the following:
2.1.1.1(a)	Vehicle passenger loading by bus stop and trip segment.
2.1.1.1(b)	Bus running times between time points.
2.1.1.1(c)	Fare collection by fare category.
2.1.1.1(d)	Drive-line operating condition.
2.1.1.1(e)	Mileage accumulated by individual buses.
2.1.1.1(f)	Real-time vehicle location reports.

2.1.1.2	OVF shall include a Command and Control (CC) capability.
2.1.1.2.1	CC shall provide the capability for real-time Vehicle Command and Control (VCC).
2.1.1.2.1.1	VCC shall provide the capability to compare received information with predetermined operating condition specifications and note any deviations.
2.1.1.2.1.2	VCC shall provide the capability to transmit noted deviations to central control.
2.1.1.2.1.3	VCC shall provide the capability to display any noted deviations.
2.1.1.2.1.4	VCC shall provide the capability to automatically issue corrective Instructions to the driver including, but not limited to, the following:
2.1.1.2.1.4(a)	Route corrections.
2.1.1.2.1.4(b)	Changes in stops.
2.1.1.2.2	When CC detects a vehicle(s) has deviated from schedule it shall provide the capability to automatically determine the optimum scenario for returning the vehicle or fleet to schedule.
2.1.1.2.3	CC shall include an integrated traffic control capability that provides traffic signal preemption when required for schedule adjustment to Transit Vehicles at traffic signals (i.e., centralized or distributed).
2.1.1.2.4	CC shall include the capability for its computational capabilities to be located either on-vehicle and/or at remote locations.
2.1.2	PTM shall include a Planning and Scheduling Services (PSS) function to automate the planning and scheduling of public transit operations.
2.1.2.1	The PSS shall include a Planning capability.
2.1.2.1.1	PSS Planning shall be performed off-line from stored data that were collected in real-time.
2.1.2.1.2	PSS Planning shall include processing of the data in a manner that will permit improvements in routes and services.
2.1.2.2	The PSS shall include a Schedule Generation capability.
2.1.2.2.1	The PSS Schedule Generation function shall collect that data needed for schedule generation including, but not limited to, the following:
2.1.2.2.1(a)	Route segment running-time.
2.1.2.2.1(b)	Passenger loading at each stop.
2.1.2.2.1(c)	Revenue information.
2.1.2.2.2	The PSS Schedule Generation function shall use the collected data in the automatic or semiautomatic development oft transportation system schedules.
2.1.2.2.3	The PSS Schedule Generation function shall provide the capability to print schedules.
2.1.2.2.4	The PSS Schedule Generation function shall provide the capability to disseminate schedules to, but not be limited to, the following:
2.1.2.2.4(a)	Kiosks.
2.1.2.2.4(b)	Transportation Management Centers.
2.1.2.2.5	The PSS Schedule Generation function shall provide the capability to automatically update the customer service operator system with the most current schedule and schedule adherence information.
2.1.3	PTM shall include a Personnel Management (PM) function to facilitate the management of both driver and maintenance personnel.
2.1.3.1	PM shall include a Maintenance Personnel Management (MPM) function.
2.1.3.1.1	MPM shall automatically track vehicle miles on each bus in real-time.
2.1.3.1.2	MPM shall use bus mileage data to automatically generate preventative maintenance schedules for each specific bus.
2.1.3.1.3	MPM shall automatically ensure that proper service personnel are provided information for bus maintenance activities.
2.1.3.1.4	MPM shall automatically assign service technicians by skill level to work on individual buses.
2.1.3.1.5	MPM shall provide the capability to record and verify that maintenance work was performed.
2.1.3.2	PM shall include a Driver Personnel Management (DPM) function.
2.1.3.2.1	DPM shall automatically generate assignments of individual drivers to route, runs and individual vehicles.
2.1.3.2.2	DPM shall assign drivers to routes and runs in a fair manner while minimizing labor and overtime costs.
2.1.3.2.3	In generating fair driver assignments DPM shall include factors relating to drivers preferences and qualifications to include, but not be limited to, the following:

2.1.3.2.3(a)	Seniority.
2.1.3.2.3(b)	Driver schedule preference.
2.1.3.2.3(c)	Garage assignment.
2.1.3.2.3(d)	Vehicle qualification.
2.1.3.2.4	DPM shall automatically track and validate the number of work hours performed by each individual driver.
2.1.4	PTM shall include a Communications function.
2.1.4.1	PTM Communications shall provide the capability to establish two-way voice communication between in vehicle drivers and the central facility.
2.1.4.2	PTM Communications shall provide the capability for two-way data communications between individual buses and the control facility (e.g., sensor data and bus position).
2.1.4 3	OVF Communications shall provide the capability to send information from individual facilities to a central facility for processing and analysis.
2.1.4.4	As support for responding to the detection of an on-board emergency, the OVF Communications shall provide dispatchers with the capability to inform the following:
2.1.4 4(a)	Police.
2.1.4.4(b)	Fire department.
2.1.4.4(c)	Paramedic.
2.1.4.4(d)	Driver (initiation of silent alarm notification).
2.1.4.5	PTM shall use an open vehicle communication network standard for all on-board electronic equipment.
2.2	EN-ROUTE TRANSIT INFORMATION
2.2.0	ITS shall include an En-Route Transit Information (TI) function. En-Route Transit Information provides travelers with real-time transit and high-occupancy vehicle information allowing travel alternatives to be chosen once the traveler is en-route. It consists of three major functions which are (1) Information Distribution, (2) Information Receipt, and (3) Information Processing. This capability integrates information from different transit modes and presents it to travelers for decision making.
2.2.1	TI shall include an information distribution function that disseminates information to travelers.
2.2.1.1	Information Distribution shall include an information network capability.
2.2.1.1.1	The Information Network shall provide the capability to furnish users with real-time travel related information while they are traveling.
2.2.1.1.2	The Information Network shall provide the capability to disseminate information to travelers that will assist them in making decisions about transfers.
2.2.1.1.3	The Information Network shall provide the capability to disseminate information to travelers that will assist them in making decisions in the modification (includes both intermode and intramode) of their trips.
2.2.1.1.4	The Information Network shall provide all users with information that is from a single source in order to ensure consistency across all users.
2.2.1.2	Information Distribution shall include a User Interface feature.
2.2.1.2.1	User Interface shall provide the capability for users to access travel related information at fixed locations.
2.2.1.2.1.1	Fixed Location user interfaces shall be provided at transit stops.
2.2.1.2.1.1.1	Transit stop user interfaces shall have interactive visual displays.
2.2.1.2.1.1.2	Transit stop user interfaces shall provide audio messages containing the following:
2.2.1.2.1.1.2(a)	Notification of imminent transit arrival.
2.2.1.2.1.1.2(b)	Identification of route of arriving transit vehicles.
2.2.1.2.1.1.3	Transit stop user interfaces shall provide the capability to provide information to individuals who are physically impaired.
2.2.1.2.1.2	Fixed Location user interface shall provide interactive video (e.g., cable TV) interfaces in kiosks at the following:
2.2.1.2.1.2(a)	Travel information centers.
2.2.1.2.1.2(b)	Transfer points.
2.2.1.2.1.2(c)	Wayside stops.
2.2.1.2.1.3	Fixed Location user interface shall provide the capability to utilize local ATM networks to provide travel information to users.

2.2.1.2.2	User Interface shall provide the capability for users to access travel related information at mobile locations.
2.2.1.2.2.1	Mobile Location user interfaces shall provide the capability for users, either one passenger at a time or to a group environment, to access travel related information while on board transit vehicles.
2.2.1.2.2.2	Mobile user interfaces shall provide the capability for users to access travel related information while in transit vehicles through the use of variable message signs.
2.2.1.2.2.3	Mobile user interfaces shall provide the capability for users to access travel related information via personal portable devices.
2.2.1.2.2.4	Mobile user interfaces shall include the capability to provide audible messages to the on-board users.
2.2.2	TI shall include an Information Receipt function for acquiring that data that are used for generation of the En-Route Transit Information.
2.2.2.1	Information Receipt shall provide the capability to be continuously updated with real-time information from each transit system within the local area of jurisdiction.
2.2.2.2	Information Receipt shall provide the capability to be updated with information that is inclusive of all possible transportation modes within the local area of jurisdiction.
2.2.2.3	Information Receipt shall provide the capability to be updated with information from all providers of transportation services in the local area of jurisdiction to include:
2.2.2.3(a)	Regional Paratransit services.
2.2.2.3(b)	Public providers.
2.2.2.3(c)	Private providers.
2.2.3	TI shall include an Information Processing function for processing that data used for generation of the En-Route Transit Information.
2.2.3.1	Information Processing shall include an information collection feature.
2.2.3.1.1	Information Collection shall acquire transit operations information to include, but not be limited to, the following:
2.2.3.1.1(a)	Schedule.
2.2.3.1.1(b)	Actual service provided.
2.2.3.1.1(c)	Next available vehicle; based on actual operating conditions.
2.2.3.1.1(d)	Transfer options describing available services and their associate schedules.
2.2.3.1.2	Information Collection shall acquire transit situation conditions to include, but not be limited to, the following:
2.2.3.1.2(a)	Actual road data.
2.2.3.1.2(b)	Traffic data.
2.2.3.2	Information Processing shall include an information integration feature.
2.2.3.2.1	Information Integration shall collect data, store it and maintain it on-line.
2.2.3.2.2	Information Integration shall collect data from traffic and transit systems including, but not limited to, the following:
2.2.3.2.2(a)	Transit systems.
2.2.3.2.2(b)	Traffic management services.
2.2.3.2.2(c)	Rideshare programs.
2.3	PERSONALIZED PUBLIC TRANSIT
2.3.0	ITS shall include a Personalized Public Transit (PPT) function.
2.3.1	The PPT shall include a Rider Request function.
2.3.1.1	Rider Request shall provide the capability for an individual rider to request a trip by specifying the trip origin and destination, time and date.
2.3.1.2	Rider Request shall provide the capability for an individual to specify a rider's special equipment or handling requirements.
2.3.1.3	Rider Request shall provide the capability to notify a requester of the fact that a trip assignment has been made including the time at which the vehicle is expected at the point of departure.
2.3.1.4	Rider Request shall include the capability to notify the requester that the transit vehicle's arrival is imminent.
2.3.2	The PPT shall include a Vehicle Assignment function.
2.3.2.1	Vehicle Assignment shall utilize vehicle availability, special requirements and rides requested information to determine vehicle assignments and routing.

2.3.2.2	For Random Route operations Vehicle Assignment shall assign trip origin and destination.
2.3.2.3	For Flexibly Routed operations Vehicle Assignment shall control how fixed route buses are detoured.
2.3.2.4	For reservation based random-route operations Vehicle Assignment shall provide the capability to plan routes that optimize vehicle schedules while considering passenger's needs.
2.3.2.5	Vehicle Assignment shall provide the capability to select the best match between the rider's needs and the available vehicles.
2.3.2.6	Vehicle Assignment shall provide services to both publicly owned and privately owned, publicly licensed vehicles.
2.3.2.7	In order to service travelers in low-demand time (e.g., night time and weekends) Vehicle Assignment shall provide services 24 hours per day, 7 days per week.
2.3.2.8	Vehicle Assignment shall assign vehicle routes within 4 blocks of rider's trip origin point.
2.3.2.9	Vehicle Assignment shall be a real-time system.
2.3.2.10	Vehicle Assignment shall provide the capability to accommodate immediate trip requests when enough capacity is available for the added rider pickup and delivery.
2.3.3	The PPT shall include a Data Collection function.
2.3.3.1	Data Collection shall include on-board sensors to monitor, but not be limited to, the following:
2.3.3.1(a)	Vehicle location.
2.3.3.1(b)	Passenger loading.
2.3.3.1(c)	Fare collection.
2.3.3.2	Data Collection shall process and store collected data so that it is available for:
2.3.3.2(a)	Real-time schedule adjustments.
2.3.3.2(b)	Off-line analysis and planning.
2.3.3.3	Data Collection shall support the off-line billing for fares paid by agencies.
2.3.4	The PPT shall include an Information Processing function.
2.3.4.1	PPT shall be implemented such that Information Processing may be located either centrally or distributed.
2.3.4.2	Information Processing shall use information to attempt to minimize the amount of time each passenger must ride.
2.3.4.3	Information Processing shall provide the capability to automate the assignment of drivers to vehicles.
2.3.5	The PPT shall include a Communications function.
2.3.5.1	The Communications function shall provide the capability link all PPT service into a single entity.
2.3.5.2	The Communications function shall provide a two-way communications capability between vehicles and a central base for:
2.3.5.2(a)	Voice communications.
2.3.5.2(b)	Data communications.
2.3.5.3	The Communications function shall provide the capability for sensor data (either raw or processed) to be transmitted from vehicles to a central headquarters or dispatch station.
2.3.5.4	The Communications function shall provide the capability for data to be transferred between dispersed points and central base including:
2.3.5.4(a)	Data from vehicles.
2.3.5.4(b)	Data from locations where passengers are located.
2.4	PUBLIC TRAVEL SECURITY
2.4.0	ITS shall include a Public Travel Security (PTS) function to create an environment of safety in public transportation.
2.4.1	PTS shall include specific Secure Areas.
2.4.1.1	The Secure Areas shall encompass all physical areas related to public transit travel including the following:
2.4.1.1(a)	Bus stop areas.
2.4.1.1(b)	Park and Ride areas.
2.4.1.1(c)	Riding on transit vehicles.
2.4.1.1(d)	Kiosks.
2.4.1.1(e)	Transit transfer locations.
2.4.1.2	All Secure Areas shall have traveler activated alarms.

2.4.1.3	There shall be included silently activated alarms on board public transit vehicles which are capable of activation by the driver.
2.4.2	PTS shall include a Security Sensors (SS) function.
2.4.2.1	SS shall provide that sensor technology required to alert operators and police of potential incidents.
2.4.2.2	SS shall include both video and audio systems at key locations to monitor activities.
2.4.3	PTS shall include a Personal Sensors Items (PSI) function.
2.4.3.1	PSI for ridematching shall include the capability for participants to be identified.
2.4.3.2	PSI shall provide the capability for riders to use electronic payment to eliminate the need for passengers to carry cash and to reduce cash handling.
2.4.4	PTS shall include a Security Management and Control (SMC) function.
2.4.4.1	SMC shall provide the capability to receive alarm information through electronic communication systems.
2.4.4.2	SMC shall include that monitoring equipment needed to assist in responding to terrorist incidents.
2.4.4.3	SMC shall include the capability for transit operators to direct and control fleet operations in a manner that supports law enforcement and emergency response agencies with flexible and responsive transportation for large numbers of people.
2.4.4.4	SMC shall include the capability to generate coordinated preplanned responses for incidents.
2.4.4.5	SMC shall include the capability to support coordinated multiple agency responses to incidents.
3.0	ELECTRONIC PAYMENT
3.1	ELECTRONIC PAYMENT SERVICES
3.1.0	ITS shall include an Electronic Payment capability. Electronic Payment Services allows travelers to pay for transportation services by electronic means. Four functions are provided which are (1) Electronic Toll Collection, (2) Electronic Fare Collection, (3) Electronic Parking Payment, and (4) Electronic Payment Services Integration.
3.1.1	Electronic Payment shall provide an Electronic Toll Collection (ETC) capability.
3.1.1.1	ETC shall provide the capability for vehicle operators to pay toll without stopping their vehicles.
3.1.1.2	ETC shall provide the capability to implement pricing structures for locally determined needs.
3.1.1.3	ETC shall provide confirmation of the transaction to each customer.
3.1.1.4	ETC shall include the capability to identify those vehicles and/or operators that violate its toll collection process.
3.1.1.5	ETC shall accommodate single billing to commercial carriers.
3.1.1.6	ETC shall provide the capability to automatically access and process each commercial vehicle's required documentation.
3.1.1.7	ETC shall be implemented in a manner that reduces the cost of toll collection.
3.1.1.8	ETC shall be implemented in a manner that seeks to minimize the opportunities for fraud.
3.1.2	Electronic Payment shall include an Electronic Fare Collection (EFC) capability.
3.1.2.1	EFC shall be implemented in a manner that the traveler is able to use a compatible fare medium for all applicable surface transportation services.
3.1.2.2	EFC shall provide the capability to implement variable and flexible fare structures.
3.1.2.3	EFC shall be capable of identifying voided and/or invalid payment media.
3.1.2.4	EFC shall provide the capability for third party payment of transportation services.
3.1.2.5	For those systems requiring special eligibility, EFC shall provide the capability to verify the eligibility of riders.
3.1.2.6	EFC shall be implemented in a manner that permits expansion into other uses for the payment medium such as payment of retail, telephone, etc.
3.1.2.7	EFC shall include the capability to collect that data that are required to determine accurate ridership levels.
3.1.2.8	EFC shall provide the capability for passengers to pay fares without stopping.
3.1.3	Electronic Payment shall include an Electronic Parking Payment (EPP) capability.
3.1.3.1	EPP shall provide the capability to pay for parking without the use of cash.
3.1.3.2	EPP shall include the capability for transit operators to utilize a single medium to charge for both transit related charges and parking charges.
3.1.3.3	EPP shall provide the capability to provide flexible pricing parking fee structures based upon factors including, but not limited to, vehicle classification.
3.1.4	ITS shall include an Electronic Payment Services Integration (EPSI) feature.

3.1.4.1	EPSI shall provide the capability to combine electronic payments made for use of various transportation modes into a single integrated system.
3.1.4.2	EPSI shall provide the capability to integrate fare and toll pricing structures of multiple agencies.
3.1.4.3	EPSI shall collect and provide that usage data needed to develop pricing strategies that favor certain transportation modes or routes.
3.1.4.4	EPSI shall be implemented in a manner that ensures that it may be deployed across multiple agency political boundaries without degrading the services it provides.
3.1.5	ITS shall provide a Roadway Pricing (RP) capability.
3.1.5.1	RP shall provide the capability to implement various road pricing policies.
3.1.5.1.1	Road pricing policies capable of being implemented by RP shall include variable pricing.
3.1.5.2	RP shall provide the capability to implement roadway pricing strategies, developed by other services, that alleviate congestion.
3.1.5.3	RP shall provide the capability to implement roadway pricing, developed by other services, that can be used to influence mode selection.
4.0	COMMERCIAL VEHICLE OPERATIONS
4.1	COMMERCIAL VEHICLE ELECTRONIC CLEARANCE
4.1.0	ITS shall include a Commercial Vehicle Electronic Clearance (CVEC) capability.
4.1.1	CVEC shall include a Fixed Facility consisting of those structures and equipment to include Ports Of Entry, Inspection Stations, Weigh Stations and Toll Booths.
4.1.1.1	Fixed Facility shall provide the capability for states participation in the CVEC program to be voluntary.
4.1.1.2	Fixed Facility shall provide the capability to support the enrollment of vehicles/carriers in the CVEC program.
4.1.1.3	Fixed Facility shall provide the capability to accommodate both interstate and intrastate vehicles/carriers.
4.1.1.4	Fixed Facility shall include that processing needed to issue pull-in for safety inspection signals of the following:
4.1.1.4(a)	Automatically generated from Pass/Need To Stop tests.
4.1.1.4(b)	Randomly generated.
4.1.1.4(c)	Manually generated.
4.1.1.5	Fixed Facility shall provide the facility operator the capability to manually override the issuance of automatically and randomly generated Pull-In requests.
4.1.1.6	When making the "Pass/Need To Stop" determination the Fixed Facility shall perform checks on the following:
4.1.1.6(a)	Vehicle/Carrier Safety Information.
4.1.1.6(b)	Vehicle Credentials.
4.1.1.6(c)	Driver Credentials/Status.
4.1.1.6(d)	Vehicle Weight Information.
4.1.1.6(e)	Tax Payment Account.
4.1.1.7	Fixed Facility shall provide the capability to establish two-way communications with each vehicle approaching the facility.
4.1.1.8	Fixed Facility shall include the capability to access and quickly update information on vehicle problems that are detected.
4.1.2	CVEC shall include a Vehicle System capability.
4.1.2.1	Vehicle System shall provide the capability to accommodate both interstate and intrastate carriers.
4.1.2.2	Vehicle System shall provide the capability for each vehicle to establish two-way communications with fixed facilities.
4.2	AUTOMATED ROADSIDE SAFETY INSPECTION
4.2.0	Vehicle System shall provide the capability for each individual vehicle's or carrier's participation in the process to be on a voluntary basis.
4.2.1	ITS shall include an Automated Roadside Safety Inspection (ARSI) capability.
4.2.2	The ARSI capability shall include a Roadside Facility (RF) function that improves the ability to perform safety inspection through the use of automation.
4.2.2.1	RF shall provide a processing capability that automates the roadside inspection tasks.
4.2.2.2	RF shall include the capability to perform brake inspections at the roadside.

4.2.2.3	RF shall include the capability for operators to use hand held devices to rapidly inspect vehicle and driver components that produce the following:
4.2.2.3(a)	Pass/Fail results.
4.2.2.3(b)	Data on actual condition.
4.2.2.3(c)	Data on expected life projections.
4.2.2.4	RF shall collect, store, maintain and provide real-time on-line interactive access to historical safety data at the roadside facility.
4.2.2.5	RF shall provide the capability to continuously update information flags for the following:
4.2.2.5(a)	Office of Motor Carriers (OMC) carrier ratings.
4.2.2.5(b)	Vehicle/driver inspection and maintenance data.
4.2.2.5(c)	Verification of repairs and out-of-service records.
4.2.2.5(d)	Driver status (including licensing and citations).
4.2.2.6	RF shall provide the capability to automatically identify to the enforcement personnel approaching vehicles that have been flagged as potentially needing maintenance or put out of service.
4.2.2.7	RF shall provide the capability to receive identification data from each vehicle that is stopped at the inspection station that enables the access and receipt at the roadside of historical safety records to include the following:
4.2.2.7(a)	Carrier.
4.2.2.7(b)	Vehicle.
4.2.2.7(c)	Driver.
4.2.2.7(d)	Cargo.
4.2.3	The ARSI capability shall include a Vehicle System (VS) function.
4.2.3.1	VS shall provide a processing capability that automates the roadside inspection tasks.
4.2.3.2	The VS architecture shall provide the capability to be developed and integrated as a phased implementation.
4.2.3.3	The VS shall include those sensors needed to efficiently check vehicle systems and driver condition.
4.2.3.4	The VS shall include the capability for continuous updates to vehicle safety records or an "electronic decal/record on the vehicle.
4.2.3.5	The VS shall include an on-board safety status monitoring system that is accessible from the roadside.
4.2.3.6	The VS shall provide an initial automated inspection capability that will expedite and supplement the existing visual and manual inspection processes.
4.2.3.7	The VS shall provide a two-way Communications capability that facilitates the roadside inspection tasks.
4.3	ON-BOARD SAFETY MONITORING
4.3.0	ITS shall include an On-Board Safety Monitoring (OBSM) function, that provides monitoring and warnings of safety problems. Of primary importance is to inform the driver, as soon as possible, of any problem that has been detected. Of secondary importance is notifying the carrier of detected safety problems. Last in importance is the notification of appropriate enforcement agencies. Requirements for On-Board Safety Monitoring are given below:
4.3.1	OBSM shall include a Fixed Facility (FF) capability for the analysis and control of safety information.
4.3.1.1	The FF shall provide the capability to analyze data received from each vehicle approaching and determine the identification of:
4.3.1.1(a)	Vehicle.
4.3.1.1(b)	Driver.
4.3.1.2	The FF shall provide the capability to provide warnings of any safety problem that has been identified.
4.3.1.3	The FF shall provide capability to log the passing of each vehicle and the associated results from the decision of whether to request the vehicle to pull in or continue without stopping.
4.3.1.4	The FF shall provide the capability to automatically make a decision as to whether to allow each vehicle to pass or require them to stop for a check.
4.3.1.5	The FF shall provide the capability for enforcement officials to manually override the automatically generated decision for vehicles to pull-in for safety inspection.
4.3.1.6	The FF shall provide the capability to perform pre-trip and post-trip inspections of each vehicle.

4.3.1.7	The FF shall provide the capability to have two-way data exchange between the Roadside facility and each vehicle.
4.3.2	OBSM shall include a Vehicle System (VS) that is a part of each vehicle.
4.3.2.1	The VS shall provide the capability to collect and process that information required to supply those roadside facilities being encountered at mainline speeds with each vehicle's safety status to include the following:
4.3.2.1(a)	Vehicle safety status.
4.3.2.1(b)	Cargo safety status.
4.3.2.1(c)	Driver safety status.
4.3.2.1(d)	Vehicle Identification.
4.3.2.1(e)	Driver Identification.
4.3.2.2	The VS shall provide the capability to alert the vehicle driver whenever there is a critical safety problem or potential emergency.
4.3.2.3	The VS shall provide the capability to have two-way data exchange between each Roadside facility encountered and the vehicle.
4.4	COMMERCIAL VEHICLE ADMINISTRATIVE PROCESSES
4.4.0	VHS shall include a Commercial Vehicle Administrative Process (CVAP) function consisting of 3 subservices to include Electronic Purchase Of Credentials, Automated Mileage and Fuel Reporting and Auditing, and International Border Electronic Clearance.
4.4.1	CVAP shall include an Electronic Purchase Of Credentials (EPC) function with capabilities that include but are not limited to the following:
4.4.1(a)	Annual Electronic Credentials.
4.4.1(b)	Temporary Electronic Credentials.
4.4.1(c)	Order Forms Computer Input Screens.
4.4.1(d)	Multiple Permits.
4.4.1(e)	Specific Situation Permits.
4.4.1(f)	Electronic Payment.
4.4.1(g)	Automated Processing of Applications.
4.4.2	CVAP shall include an Automated Mileage and Fuel Reporting and Auditing (AMFPA) function that includes but is not limited to the following:
4.4.2(a)	Quarterly Reports Submission.
4.4.2(b)	Electronic Vehicle Log.
4.4.2(c)	Fuel Purchase Data.
4.4.2(d)	Create And Audit Tax Reports.
4.4.3	CVAP shall include an International Border Electronic Clearance (IBEC) function.
4.4.3.1	IBEC provides the capability to Electronically clear for vehicles crossing international borders with those countries adjacent to the United States. IBEC shall provide the capability to clear the following:
4.4.3.1(a)	Driver Clearance.
4.4.3.1(b)	Cargo Clearance.
4.4.3.1(c)	Vehicle.
4.4.3.2	IBEC shall have an Electronic Records function that enables certification of border crossing shipment with the verification capabilities to include but not be limited to the following:
4.4.3.2(a)	Verify driver identity.
4.4.3.2(b)	Verify shipper.
4.4.3.2(c)	Verify Nature of cargo.
4.4.3.2(d)	Verify Carrier safety.
4.4.3.2(e)	Verify credential records.
4.4.3.2(f)	Verify Duties Paid.
4.4.3.2(g)	Verify Vehicle Identity.
4.4.3.2(h)	Verify Vehicle Weight.
4.5	HAZARDOUS MATERIAL INCIDENT RESPONSE
4.5.0	ITS shall include an hazardous Materials (HAZMAT) Incident Response (HIR) service.
4.5.1	HIR shall include a HAZMAT Incident Notification (HIN) function.
4.5.1.1	HIN shall include the capability to provide enforcement and HAZMAT response teams with timely and accurate information on cargo contents when the vehicle is involved in an incident.

4.5.1.2	HIN shall be capable of providing the following Information:
4.5.1.2(a)	Time of incident.
4.5.1.2(b)	Location of the incident.
4.5.1.2(c)	The material(s) involved.
4.5.2	HIR shall provide an Operation Focal Point (OFP) for initiating appropriate responses.
4.5.2.1	OFP shall be capable of being implemented as either a centralized dispatch or several de-centralized dispatch units or vehicles.
4.5.2.2	OFP shall provide the capability for existing dispatch centers to receive the calls, determine response requirements, and route distress calls to predesignated responding agencies.
4.5.2.3	OFP shall provide the capability for operators to coordinate with other agencies and response services to include, but not be limited to, the following:
4.5.2.3(a)	State and/or local transportation officials.
4.5.2.3(b)	Police departments.
4.5.2.3(c)	Highway patrol.
4.5.2.3(e)	Emergency medical services.
4.5.2.3(f)	Environmental protection agencies.
4.5.2.3(g)	HAZMAT teams.
4.5.2.3(h)	Towing and other "courtesy" services.
4.5.3	HIR shall include a Communications (COMM) function.
4.5.3.1	COMM shall provide the capability for distress signals to be sent to a focal point.
4.5.3.2	COMM shall provide the capability for relay of distress information to response units in real-time.
4.5.3.3	COMM shall provide the capability for data to be sent from any location covering all areas of the contiguous United States.
4.5.3.4	COMM shall provide the capability for linkages/interfaces with various existing networks.
4.5.3.5	COMM shall provide the capability for the motorist to travel from region to region without performing manual adjustment of equipment.
4.6	COMMERCIAL FLEET MANAGEMENT
4.6.0	ITS shall include a Commercial Fleet Management (CFM) function.
4.6.1	CFM shall include the capability for users to provide commercial drivers and dispatchers with real-time routing information in response to congestion or incidents.
4.6.2	CFM shall provide the capability for real-time communication between the following:
4.6.2(a)	Vehicle Drivers.
4.6.2(b)	Dispatchers.
4.6.2(c)	Intermodal Transportation Providers.
5.0	EMERGENCY MANAGEMENT
5.1	EMERGENCY NOTIFICATION AND PERSONAL SECURITY
5.1.0	ITS shall include an Emergency Notification And Personal Security (ENPS) function that provides for the faster notification of travelers involved in an incident.
5.1.1	ENPS shall include a Driver and Personal Security (DPS) function.
5.1.1.1	DPS shall include an in-vehicle manually initiated distress signal capability to provide a first-alert that incident has occurred to include the following:
5.1.1.1(a)	Medical services required.
5.1.1.1(b)	Minor property damage only crashes.
5.1.1.1(c)	Breakdowns.
5.1.1.1(d)	Vehicle location.
5.1.1.1(e)	Vehicle identification.
5.1.1.2	DPS shall include the capability to cancel a prior issued manual request for help.
5.1.1.3	DPS shall include the capability to send an acknowledge signal to the motorist to indicate that the signal was received and help is on the way.
5.1.1.4	DPS shall include the capability for in-vehicle sensors to automatically detect vehicle problems, and for certain cases automatically send the appropriate distress signal.
5.1.2	ENPS shall include an Automated Collision Notification (ACN) function.
5.1.2.1	ACN shall provide the capability to automatically identify that a collision has occurred.
5.1.2.1.1	The ACN automatic collision notification function shall provide the capability to instantly transmit information about the occurrence of a collision.

5.1.2.1.2	The ACN crash sensors shall include the capability to provide information about the extent of crash damage.
5.1.2.2	When sending notification of a collision ACN shall send pertinent information about the collision including the following:
5.1.2.2(a)	That vehicle has been in a collision.
5.1.2.2(b)	Accurate vehicle location.
5.1.2.2(c)	Severity of collision and/or injuries.
5.2	EMERGENCY VEHICLE MANAGEMENT
5.2.0	ITS shall include an Emergency Vehicle Management (EVM) Service.
5.2.1	Emergency Vehicle Management Service shall be provided by an Emergency Vehicle Fleet Management System.
5.2.1.1	Emergency Vehicle Fleet Management System shall maintain the availability status of relevant emergency vehicles.
5.2.1.2	Emergency Vehicle Fleet Management System shall determine the emergency response vehicles best suited to respond to an incident.
5.2.1.3	Emergency Vehicle Fleet Management System shall dispatch the appropriate emergency response vehicle (s) to the incident.
5.2.2	Emergency Vehicle Management Service shall be provided by a Route Guidance System.
5.2.2.1	Route Guidance System shall maintain real-time information on traffic conditions, emergency response vehicle locations, and emergency response vehicle destinations.
5.2.2.2	Route Guidance System shall advise emergency response vehicles of appropriate routes.
5.2.3	Emergency Vehicle Management Service shall be provided by a Signal Priority System.
5.2.3.1	Signal Priority System shall maintain real-time information on signal timing, emergency vehicle locations and emergency vehicle routing.
5.2.3.2	Signal Priority System shall determine signal prioritize timing sequences for relevant signals.
6.0	ADVANCED VEHICLE SAFETY SYSTEMS
6.1	LONGITUDINAL COLLISION AVOIDANCE
6.1.0	ITS Shall include a Longitudinal Collision Avoidance Service.
6.1.1	Longitudinal Collision Avoidance Service shall include a Rear-End Subservice.
6.1.1.1	Rear-End Subservice shall be provided by a Headway Maintenance System which assists in maintaining a saferelative longitudinal separation between vehicles.
6.1.1.1.1	Headway Maintenance System shall include a Manual Operations Subsystem.
6.1.1.1.1.1	Manual Operations Subsystem shall determine impending situations that are inconsistent with safe headway.
6.1.1.1.1.2	Manual Operations Subsystem shall alert the vehicle's driver of the need for speed control to maintain a safe headway.
6.1.1.1.2	Headway Maintenance System shall include an Autonomous Intelligence Cruise Control (AICC) Subsystem.
6.1.1.1.2.1	Autonomous Intelligence Cruise Control Subsystem shall determine actions necessary to maintain the vehicle at a safe distance behind a lead vehicle.
6.1.1.1.2.2	Autonomous Intelligence Cruise Control Subsystem shall implement necessary vehicle speed control.
6.1.1.1.3	Headway Maintenance System shall include a Cooperative Intelligence Cruise Control (CICC) Subsystem.
6.1.1.1.3.1	Cooperative Intelligence Cruise Control Subsystem shall be capable of operating the vehicle in a follow-lead-vehicle mode or a "platoon" mode.
6.1.1.2	Rear-End Subservice shall be provided by a Driver Action System.
6.1.1.2.1	Driver Action System shall inform the driver of the need for immediate collision avoidance action.
6.1.1.3	Rear-End Subservice shall be provided by an Automatic Control System.
6.1.1.3.1	Automatic Control System shall automatically implement needed collision avoidance action.
6.1.2	Longitudinal Collision Avoidance Service shall include a Backing Subservice.
6.1.2.1	Backing Subservice shall be provided by an Advisory System.
6.1.2.1.1	Advisory System shall notify the driver of the presence of potentially hazardous situations.
6.1.2.2	Backing Subservice shall be provided by a Driver Action System.
6.1.2.2.1	Driver Action System shall inform the driver of the need for immediate collision avoidance action.
6.1.2.3	Backing Subservice shall be provided by an Automatic Control System.

6.1.2.3.1	Automatic Control System shall automatically implement needed collision avoidance action.
6.1.3	Longitudinal Collision Avoidance Service shall be provided by a Head-On/Passing Subservice.
6.1.3.1	Head-On/Passing Subservice shall be provided by an Advisory System.
6.1.3.1.1	Advisory System shall notify the driver of the presence of potentially hazardous situations.
6.1.3.2	Head-On /Passing Subservice shall include a Driver Action System.
6.1.3.2.1	Driver Action System shall inform the driver of the need for immediate collision avoidance action.
6.1.3.3	Head-On/Passing Subservice shall be provided by an Automatic Control System.
6.1.3.3.1	Automatic Control System shall automatically implement needed collision avoidance action.
6.2	LATERAL COLLISION AVOIDANCE
6.2.0	ITS shall include a Lateral Collision Avoidance Service.
6.2.1	Lateral Collision Avoidance Service shall include a Lane Change/Merge Subservice.
6.2.1.1	Lane Change/Merge Subservice shall be provided by an Advisory System.
6.2.1.1.1	Advisory System shall notify the driver of the presence of potentially hazardous situations.
6.2.1.2	Lane Change/Merge Subservice shall be provided by a Driver Action System.
6.2.1.2.2	Driver Action System shall inform the driver of the need for immediate collision avoidance action.
6.2.1.3	Lane Change/Merge Subservice shall be provided by an Automatic Control System.
6.2.1.3.1	Automatic Control System shall automatically implement needed collision avoidance action.
6.2.2	Lateral Collision Avoidance Service shall include a Single Vehicle Roadway Departure (SVRD) Subservice.
6.2.2.1	Single Vehicle Roadway Departure Subservice shall be provided by an Advisory System.
6.2.2.1.1	Advisory System shall notify the driver of the presence of a potentially hazardous situation.
6.2.2.2	Single Vehicle Roadway Departure Subservice shall be provided by a Driver Action System.
6.2.2.2.1	Driver Action System shall inform the driver of the need for immediate collision avoidance action.
6.2.2.3	Single Vehicle Roadway Departure Subservice shall be provided by an Automatic Control System.
6.2.2.3.1	Automatic Control system shall automatically implement needed collision avoidance action.
6.3	INTERSECTION COLLISION AVOIDANCE
6.3.0	ITS shall include an Intersection Crash Collision Avoidance Service.
6.3.1	Intersection Collision Avoidance Service shall be provided by an Advisory System.
6.3.1.1	Advisory System shall notify the driver of the presence of potentially hazardous situations.
6.3.2	Intersection Collision Avoidance Service shall be provided by a Driver Action System.
6.3.2.1	Driver Action System shall notify the driver of the need for immediate collision avoidance action.
6.3.3	Intersection Collision Avoidance Service shall be provided by an Automatic Control System.
6.3.3.1	Automatic Control system shall automatically implement needed collision avoidance action.
6.4	VISION ENHANCEMENT FOR CRASH AVOIDANCE
6.4.0	ITS shall include a Vision Enhancement for Crash Avoidance Service.
6.4.1	Vision Enhancement for Crash Avoidance Service shall be provided by an Enhanced Vision System, which augments the vehicle operator's capability to see pedestrians and hazardous situations, where driving visibility is low.
6.5	SAFETY READINESS
6.5.0	ITS shall include a Safety Readiness Service.
6.5.1	Safety Readiness Service shall include a Driver Monitor Subservice.
6.5.1.1	Driver Monitor Subservice shall be provided by an Advisory/Control System.
6.5.1.1.1	Advisory/Control System shall determine the driver's readiness.
6.5.1.1.2	Advisory/Control System shall notify the driver of need to take corrective action.
6.5.1.1.3	Advisory/Control System shall automatically counteract insufficient driver's readiness to operate the vehicle by safely stopping the vehicle.
6.5.2	Safety Readiness Service shall include a Vehicle Condition Subservice.
6.5.2.1	Vehicle Condition Subservice shall be provided by an Advisory System.
6.5.2.1.1	Advisory System shall determine the condition of critical vehicle components.
6.5.2.1.2	Advisory System shall notify the driver of need to take corrective action.
6.5.3	Safety Readiness Service shall include an Infrastructure Condition Subservice.
6.5.3.1	Infrastructure Condition Subservice shall be provided by an In-Vehicle Infrastructure Advisory System.
6.5.3.1.1	In-Vehicle Infrastructure Advisory System shall determine unsafe roadway conditions.

6.5.3.1.2	In-Vehicle Infrastructure Advisory System shall a notify the driver of the need to take corrective action.
6.6	PRE-CRASH RESTRAINT DEPLOYMENT
6.6.0	ITS shall include the Pre-Crash Restraint Deployment Service.
6.6.1	Pre-Crash Restraint Deployment Service shall be provided by an Automatic Activation System.
6.6.1.1	Automatic Activation System shall detect an impending collision with a moving or a stationary object prior to crash impact.
6.6.1.2	Automatic Activation System shall initiate pre-impact deployment of restraint devices when appropriate to reduce injury severity.
6.7	AUTOMATED VEHICLE OPERATION
6.7.0	ITS shall include a Automated Vehicle Operation Service (AVO).
6.7.1	AVO service shall be provided by an Automated Highway System (AHS); the Target Level System.
6.7.1.1	AHS shall include an Automated Check-In Subsystem (ACIS).
6.7.1.1.1	The ACIS shall include the capability for the driver to initiate a transaction, including indication of destination, with the AHS.
6.7.1.1.2	The ACIS shall be capable of determining the vehicle qualifications for access to AHS.
6.7.1.1.3	The ACIS shall be capable of safely controlling access to AHS.
6.7.1.2	AHS shall include a Vehicle Control Subsystem (VCS).
6.7.1.2.1	VCS shall be capable of determining the condition, location, and motion of each vehicle on the automated lanes.
6.7.1.2.2	VCS shall determine the conditions for safe operation of vehicles on the automated lanes.
6.7.1.2.3	VCS shall automatically control the vehicles on AHS.
6.7.1.3	AHS shall include an Automated Check-Out Subsystem (ACOS).
6.7.1.3.1	ACOS shall determine the readiness of the vehicle operator to resume control of the vehicle.
6.7.1.3.2	ACOS shall be capable of safely controlling egress from AHS.
6.7.2	AVO service shall be provided by a Partially Automated Highway System (PAHS) as a Transitional System.
6.7.2.1	PAHS shall include Vehicle Subsystems which utilize capabilities of collision avoidance systems and other systems to implement safe "platooning" and other transitional levels of performance.
6.7.2.2	PAHS shall include a Highway Subsystem which utilizes capabilities of Advanced Highway Infrastructure systems to assist in providing better control of vehicle routes.
6.7.2.3	PAHS shall include a Driver Subsystem which utilizes capabilities of driver alertness systems and other systems to assist in managing vehicles in situations other than full automatic control.
6.7.2.3	The following services and requirements are not yet officially integrated in the ITS National Architecture
7.0	Information Management
7.1	Archived Data Function
7.1.0	ITS shall provide an Archived Data Function to control the archiving and distribution of ITS data. The Archived Data User Service provides the Historical Data Archive Repositories and controls the archiving functionality for all ITS data with five major functions: 1) the Operational Data Control function to manage operations data integrity; 2) the Data Import and Verification function to acquire historical data from the Operational Data Control function; 3) the Automatic Data Historical Archive function for permanently archiving the data; 4) the Data Warehouse Distribution function, which integrates the planning, safety, operations, and research communities into ITS and processes data products for these communities; and 5) the ITS Community Interface which provides the ITS common interface to all ITS users for data products specification and retrieval. ADUS helps achieve the ITS information goal of unambiguous interchange and reuse of data and information throughout all functional areas.
7.1.1	The Archived Data Function shall provide a Historical Data Archive (HDA) system for ITS data.
7.1.1.1	HDA shall include repositories of operational datas received from field equipment or data collection devices.
7.1.1.2	HDA shall provide permanent historical data repositories.
7.1.1.3	HDA repositories shall include meta data and meta-attributes repositories.
7.1.1.4	HDA shall provide ITS data system security.
7.1.1.4.1	HDA shall be capable of employing security solutions.

7.1.1.4.2	HDA shall be capable of preventing data loss.
7.1.1.4.3	HDA shall be capable of preventing unauthorized access to ITS data repositories
7.1.1.4.4	HDA shall be capable of providing a secure interface for online support of the ITS user interface.
7.1.1.5	HDA shall be capable of supporting online analytical functions to enable users to analyze data across multiple sources or acquire data for their off-line applications.
7.1.2	The Archived Data Function shall include an Operational Data Control (ODC) function to ensure integrity of operational data as received from field equipment or data collection devices.
7.1.2.1	ODC shall be capable of receiving and storing all ITS operational data, as received from the source.
7.1.2.1.1	ODC shall ensure ITS operational data are in proper format.
7.1.2.1.2	ODC shall maintain the meta data schema for all ITS data entering the system.
7.1.2.1.3	ODC shall be capable of assigning the following meta attributes, when available, to ITS operational data during the archive process.
7.1.2.1.3(a)	The equipment used to collect the data.
7.1.2.1.3(b)	The conditions under which the data were collected.
7.1.2.1.3(c)	The status of the equipment at the time of collection.
7.1.2.1.4	ODC shall be capable of applying user-defined quality control verification on ITS data and annotating results in the appropriate meta files.
7.1.2.1.5	ODC shall be capable of assigning meta-attributes to the data indicating the methods used to perform:
7.1.2.1.5(a)	summarization and aggregation
7.1.2.1.5(b)	transformations (i.e., reconstructing original data or constructing new data elements)
7.1.2.2	ODC shall be capable of collecting user-selected data.
7.1.2.3	ODC shall be capable of archiving in data repositories ITS operational data as received from field equipment or data collection devices.
7.1.2.4	ODC shall be capable of maintaining the integrity of all received operational data.
7.1.2.5	ODC shall be capable of disseminating data replicates to ITS operational users in real-time.
7.1.2.6	ODC shall be capable of performing data fusion on replicated data for operational users in near real-time.
7.1.3	The Archived Data Function shall include a Data Import and Verification (DIV) function to acquire historical data from the Operational Data Control function.
7.1.3.1	DIV shall be capable of importing selected ITS Operational data from the ITS Operational Repositories.
7.1.3.1.1	DIV shall be capable of importing ITS Freeway Operations data to include:
7.1.3.1.1(a)	Freeway traffic flow surveillance data.
7.1.3.1.1(b)	Ramp meter preemptions.
7.1.3.1.1(c)	Ramp meter operational data.
7.1.3.1.1(d)	Freeway visual and video surveillance data.
7.1.3.1.1(e)	Traffic Management Center generated freeway flow metrics.
7.1.3.1.10	DIV shall be capable of importing ITS Parking Management data.
7.1.3.1.11	DIV shall be capable of importing Intermodal Operational data.
7.1.3.1.2	DIV shall be capable of importing ITS Electronic Toll Collection data.
7.1.3.1.3	DIV shall be capable of importing ITS Arterial data to include:
7.1.3.1.3(a)	Traffic signal preemptions.
7.1.3.1.3(b)	Traffic signal operational data.
7.1.3.1.3(c)	Arterial visual and video surveillance data.
7.1.3.1.3(d)	Traffic Management Center generated arterial flow metrics.
7.1.3.1.3(e)	Arterial traffic flow surveillance data.
7.1.3.1.4	DIV shall be capable of importing ITS Transit and Ridesharing data to include:
7.1.3.1.4(a)	Transit usage data.
7.1.3.1.4(b)	Transit route data including schedule deviations.
7.1.3.1.4(c)	Rideshare requests.
7.1.3.1.4(d)	Multimodal Origin/Destination.
7.1.3.1.4(e)	Fares
7.1.3.1.4(f)	Vehicle maintenance
7.1.3.1.4(g)	Personnel management data

7.1.3.1.5	DIV shall be capable of importing ITS Incident Management data to include:
7.1.3.1.5(a)	Incident characteristics.
7.1.3.1.5(b)	Train arrivals at highway rail intersections.
7.1.3.1.5(c)	Emergency vehicle dispatch data.
7.1.3.1.5(d)	Emergency vehicle location data.
7.1.3.1.5(e)	Construction and work zone identification.
7.1.3.1.5(f)	Emergency request data
7.1.3.1.5(g)	Video surveillance data
7.1.3.1.5(h)	Emergency response
7.1.3.1.6	DIV shall be capable of importing ITS Commercial Vehicle Operations data to include:
7.1.3.1.6(a)	Cargo identification data.
7.1.3.1.6(b)	Fleet activity data.
7.1.3.1.6(c)	Hazardous material packaging data.
7.1.3.1.6(d)	Border crossing data.
7.1.3.1.6(e)	Commercial vehicle on-board safety data.
7.1.3.1.6(f)	Truck Origin/Destination and Classification data
7.1.3.1.7	DIV shall be capable of importing ITS Environmental data to include:
7.1.3.1.7(a)	Emission data.
7.1.3.1.7(b)	Weather data.
7.1.3.1.8	DIV shall be capable of importing ITS Vehicle and Traveler data to include:
7.1.3.1.8(a)	Commercial and non-commercial vehicle probe data.
7.1.3.1.8(b)	VMS message set data.
7.1.3.1.8(c)	Vehicle trajectories.
7.1.3.1.8(d)	Route guidance data.
7.1.3.1.8(e)	Parking and roadway pricing change data.
7.1.3.1.8(f)	Origin/destination trip data.
7.1.3.1.8(g)	Service requests
7.1.3.1.8(h)	Information utilization
7.1.3.1.9	DIV shall be capable of importing data on ITS Physical Characteristics of Transportation Infrastructure to include:
7.1.3.1.9(a)	Roadway network attributes.
7.1.3.1.9(b)	Transit network attributes.
7.1.3.1.9(c)	Equipment maintenance status
7.1.3.1.9(d)	Transportation facilities.
7.1.3.1.9(e)	GIS map of network.
7.1.3.1.9(f)	Infrastructure maintenance data
7.1.3.2	DIV shall be capable of accepting pre-defined data inputs from transportation or other sources.
7.1.3.3	DIV shall be capable of applying pre-defined quality control verification on the imported ITS data and annotating results in the appropriate meta files.
7.1.3.4	DIV shall be capable of formatting the data to conform to the archive schema.
7.1.3.5	DIV shall be capable of cleansing imported data
7.1.3.5.1	Cleansing shall include the removal of source privacy attributes.
7.1.3.5.2	Cleansing shall be capable of assigning unique system-developed anonymous identifiers to data during archiving.
7.1.3.6	DIV shall be capable of performing pre-defined data mining functions to import data.
7.1.3.7	DIV shall be capable of performing pre-defined data fusion on imported data near real-time.
7.1.3.8	DIV shall be capable of assigning meta attributes to ITS operational data if data modification is required during the historical archive process.
7.1.3.9	DIV shall be capable of notifying source system owners of potential data or equipment errors.
7.1.4	The Archived Data function shall provide the Automatic Data Historical Archive (ADHA) function for permanently archiving the data.
7.1.4.1	ADHA shall provide an archive schema for all ITS data entering the archives.
7.1.4.1.1	The archive schema shall preclude the possibility of identifying or tracking either individual citizens or private firms.
7.1.4.1.2	ADHA shall strip all identifiers of individual citizens or private firms from all data before archiving.

7.1.4.1.3	ADHA shall be capable of assigning unique system-developed anonymous identifiers to data during archiving.
7.1.4.2	ADHA shall manage the ITS historical data archiving processes for all functional areas as follows:
7.1.4.2(a)	Format data to archive schema conformance.
7.1.4.2(b)	Maintain a centralized meta schema to specify how data is archived.
7.1.4.2(c)	Maintain data quality meta attributes.
7.1.4.2(d)	Schedule archiving of data.
7.1.4.3	ADHA shall permanently store historical archives and only provide data replicates to users.
7.1.4.4	ADHA shall be capable of supporting user-specified data archiving procedures as follows:
7.1.4.4(a)	When specified by a user, archive operational data as received in the user's storage files.
7.1.4.4(b)	When specified by a user, archive edited data in the User's storage files.
7.1.4.4(c)	When specified by a user, perform pre-defined data fusion before archiving in User's storage files.
7.1.4.5	ADHA shall be capable of assigning meta attributes to ITS operational data if data modification is required during the historical archive process.
7.1.5	The Archived Data Function shall provide a Data Warehouse Distribution (DWD) function as the ITS data source to support the ITS community user functions.
7.1.5.1	DWD shall be capable of supporting the generation of data products for the following transportation agencies:
7.1.5.1(a)	Planning
7.1.5.1(b)	Operations
7.1.5.1(c)	Safety
7.1.5.1(d)	Research
7.1.5.2	DWD shall include a User Data Products (UDP) function.
7.1.5.2.1	UDP shall provide an online analytical functionality to generate pre-defined data products for ITS users, to include:
7.1.5.2.1(a)	Reports
7.1.5.2.1(b)	Analyses
7.1.5.2.1(c)	Aggregations or summaries.
7.1.5.2.1(d)	User defined archiving of data concepts.
7.1.5.2.2	UDP shall be capable of recreating ITS operational data formats from the historical archives.
7.1.5.2.3	UDP shall be capable of providing user defined data mining functions on ITS data sources.
7.1.5.2.4	UDP shall be capable of performing user defined data fusion functions on data extracted from ITS Archives.
7.1.5.2.5	UDP shall be capable of supporting the Federal data system with user-defined data products, when the necessary data is available, to include the following systems:
7.1.5.2.5(a)	Highway Performance Monitoring System (HPMS)
7.1.5.2.5(b)	Truck Weight Study/VTRIS
7.1.5.2.5(c)	National Bridge Inventory
7.1.5.2.5(d)	Fatal Accident Reporting System (FARS)
7.1.5.2.5(e)	Highway Safety Information System (HSIS)
7.1.5.2.5(f)	Section 15 Transit Data
7.1.5.2.5(g)	Motor Carrier Management Information System (MCMIS)
7.1.5.2.5(h)	Hazardous Materials Incident Reporting System
7.1.5.2.5(i)	Grade Crossing Inventory System (GCIS)
7.1.5.2.5(j)	Railroad Accident/Incident Reporting System (RAIRS; grade crossing portion)
7.1.5.3	DWD shall have the single point of administration for the archived data system.
7.1.6	The Archived Data Function shall provide users with an ITS Community Interface (ICI) including all ITS users for the specification and retrieval of data products.
7.1.6.1	ICI shall be the common data interface for all ITS users to access the ITS Data Archives.
7.1.6.1.1	ICI shall provide users' systems with the data interface functionality.
7.1.6.2	ICI shall manage user access and security across the interface.
7.1.6.2.1	ICI shall be capable of cleansing data to remove source privacy attributes before archiving data.
7.1.6.2.2	ICI shall be capable of cleansing data to remove source privacy attributes before exporting data to users.
7.1.6.3	ICI shall provide a user-interface functionality to existing data warehouse data schema for users to define their data products.

7.1.6.3.1	The user-interface shall permit users to define access to multiple databases as data sources for their data products.
7.1.6.3.2	The user-interface shall permit users to select online analytical functions to produce their data products.
7.1.6.3.3	The user-interface shall permit the user to view sample data products.
7.1.6.4	ICI shall provide the user interface for ITS Transportation Agencies.
7.1.6.4.1	Transportation agencies shall include the following planning functions:
7.1.6.4.1(a)	Metropolitan Planning Organizations (MPO) and State Transportation Planning
7.1.6.4.1(b)	Transportation System Monitoring
7.1.6.4.1(c)	Air Quality Analysis
7.1.6.4.1(d)	MPO/State Freight and Intermodal Planning
7.1.6.4.1(e)	Land Use Regulation and Growth Management
7.1.6.4.1(f)	Transportation Administration and Policy Analysis.
7.1.6.4.1(g)	Transit Planning
7.1.6.4.2	Transportation agencies shall include the following ITS Operations functions:
7.1.6.4.2(a)	Traffic Management.
7.1.6.4.2(b)	Transit Management.
7.1.6.4.2(c)	Construction and Maintenance.
7.1.6.4.2(d)	The Private Sector.
7.1.6.4.3	Transportation functions shall include the following safety agencies:
7.1.6.4.3(a)	Safety Planning and Administration.
7.1.6.4.3(b)	Commercial Vehicle Operations.
7.1.6.4.3(c)	Emergency Management.
7.1.6.4.4	Transportation agencies shall include research agencies.

Appendix B
User Services in European ITS Architecture

1.0	General - This groups contains the properties that either the Framework Architecture should possess, or that systems built in conformance to the Framework Architecture should possess.
1.1	Architectural Properties
1.1.1	The Framework Architecture description shall include functional, information, physical and communication perspectives.
1.1.2	The Framework Architecture description shall include a number of reference models to describe the relationships between the services needed within the traffic and transport system.
1.1.3	The Framework Architecture description shall include a glossary to explain all the main concepts described in the architecture.
1.1.4	The Framework Architecture shall be provided in a form which enables it to be up-dated after delivery.
1.1.5	The Framework Architecture shall be technology independent.
1.1.6	The Framework Architecture shall facilitate the creation of modular and flexible designs.
1.1.7	The Framework Architecture shall allow equipment performing the same service to be provided by various suppliers
1.1.8	The Framework Architecture shall allow the same service to be provided by various service providers.
1.1.9	The Framework Architecture shall allow the user to select from one of a number of suppliers of the same service.
1.1.10	The Framework Architecture shall support interaction between services provided by private and public bodies.
1.1.11	The Framework Architecture shall allow current organisational responsibilities and legal liabilities to be retained.
1.1.12	The Framework Architecture shall, where possible, describe migration path(s) that can be followed to enable architectures defined for existing traffic and transport management, as well as other ITS control and information systems, to become compliant.
1.1.13	The Framework Architecture shall allow the use of existing and emerging communication infrastructures, or describe possible migration paths to explain how they can become compliant.
1.1.14	The Framework Architecture shall support the integration of Traffic Information Centres and Traffic Control Centres into national and international networks.
1.1.15	The Framework Architecture description shall identify clearly the relevant interfaces to other modes of transport.
1.2	Interoperability
1.2.1	The Framework Architecture shall provide a high level description of the message sets and data communication protocols to be used in data transfers.
1.2.2	The Framework Architecture shall provide a high level description of data stores and data flows, and shall have a single data dictionary.
1.2.3	Systems that conform to the Framework Architecture shall exchange information in a manner that permits a given geographic location to be understood by all parties.
1.2.4	Systems that conform to the Framework Architecture shall exchange information in a manner that permits road and traffic conditions to be understood by all parties.
1.2.5	The Framework Architecture shall provide a high level description of the message sets used to exchange data with external interfaces.
1.2.6	The Framework Architecture shall support the use of seamless communications (the use of different communication networks is transparent i.e. without the intervention of the final user).
1.3	Adaptability
1.3.1	Systems that conform to the Framework Architecture shall be able to provide facilities that accommodate the needs of disabled and elderly persons, when relevant.
1.3.2	Systems that conform to the Framework Architecture shall be able to provide facilities to enable data about the travel network to be entered and updated.
1.3.3	The Framework Architecture shall not constrain its functionality to be implemented in a single topographical domain, be it urban, inter-urban or rural.
1.3.4	The Framework Architecture shall not constrain its functionality to be implemented by specific local organisations.

1.3.5 The Framework Architecture shall define its user interfaces so that they can be used on a wide variety of proprietary equipment supplied by different manufacturers.

1.3.6 The Framework Architecture shall not require that each of its user interfaces must operate on a specific piece of equipment, unless it is for safety reasons.

1.4 Constraints

1.4.1 The Framework Architecture shall ensure compliance with current laws concerning data security, user anonymity and the protection of individual privacy.

1.4.2 The Framework Architecture shall comply with the traffic laws and regulations that apply in Europe.

1.4.3 The Framework Architecture shall conform to relevant MoU, European directives and guidelines, and European (de facto-) standards.

1.5 Continuity

1.5.1 The Framework Architecture shall provide functionality such that the quality of information content is continuous and consistent, both in time and space (i.e. as the traveller moves).

1.5.2 The Framework Architecture shall provide functionality that can accommodate environmental stress and infrastructure failures.

1.6 Cost/Benefit

1.6.1 Whenever possible and practical, the Framework Architecture shall use the same data as input to several parts of its functionality.

1.6.2 The Framework Architecture shall avoid the need for redundant data management, unless it is for reasons of safety.

1.6.3 The Framework Architecture shall require all systems developed from it to be able to use the most cost-effective means of communication with users of other systems.

1.6.4 The Framework Architecture shall require all systems developed from it to enable operating costs to be reduced whenever possible, when compared with the systems that they replace.

1.6.5 The Framework Architecture shall require all systems developed from it that require payment from a user to be able to manage fees/fares.

1.6.6 The Framework Architecture shall require all systems developed from it that require payment from a user to be able to receive fees/fares.

1.6.7 Systems developed from the Framework Architecture shall not, of itself, require additional expenditure to be spent on their procurement, operation or maintenance.

1.7 Expandability

1.7.1 The Framework Architecture shall allow systems developed from it to have an evolutionary development strategy that enables their continuous upgrading.

1.7.2 The Framework Architecture shall provide functionality that is not constrained by geographic scope.

1.8 Maintainability

1.8.1 The Framework Architecture shall require all systems developed from it to be capable of being repaired.

1.8.2 The Framework Architecture shall require all systems developed from it to be easily maintainable with minimum disturbance.

1.9 Quality of Data Content

1.9.1 The Framework Architecture shall require all information systems developed from it to provide data with a stated accuracy, either as additional information or as part of the documentation, at all times.

1.9.2 The Framework Architecture shall require all systems developed from it to check all input data for validity, whenever possible, and to report failures.

1.9.3 The Framework Architecture shall require all systems developed from it to check data values by comparing different sources, when available, so as to ensure high-accuracy and completeness.

1.9.4 The Framework Architecture shall require all systems developed from it to manage local/regional/national databases in a consistent way.

1.10 Robustness

1.10.1 The Framework Architecture shall allow all systems developed from it to be able to detect errors and faults, when this is desirable.

1.10.2 Systems that conform to the Framework Architecture shall be able to monitor each safety-related component (including software), warn the user in case of problems, and disable it, or reduce it to a safe state.

1.10.3 The Framework Architecture shall require all safety-related systems developed from it to be fault-tolerant.

1.10.4	The Framework Architecture shall require all systems developed from it to be reliable with respect to normal expectations.
1.10.5	The Framework Architecture shall require all systems developed from it to be able to operate in all potential climatic and traffic conditions.
1.11	Safety
1.11.1	The Framework Architecture shall provide functionality that operates in a manner that does not generate a safety hazard for its users.
1.11.2	The Framework Architecture shall provide functionality that operates in a manner that does not encourage unsafe behaviour.
1.11.3	The Framework Architecture shall provide functionality that operates in a safe manner during degraded modes of operation.
1.11.4	The Framework Architecture shall provide functionality that is ultimately under the control of the human operator.
1.12	Security
1.12.1	The Framework Architecture shall require that systems developed from it are capable of surviving accidental and intentional attacks on their integrity.
1.12.2	The Framework Architecture shall require systems developed from it to provide protection against unauthorised access.
1.13	User Friendliness
1.13.1	The Framework Architecture shall require all systems developed from it to have user interfaces with similar look and feel and similar end user assistance.
1.13.2	The Framework Architecture shall require all systems developed from it to be simple and efficient to use.
1.13.3	The Framework Architecture shall require all systems developed from it to have a user interface syntax that is easy to learn and to remember (especially for users with specific needs).
1.13.4	Systems developed from the Framework Architecture shall produce their output within a time that is sufficient to be useful, and within normal expectations.
1.13.5	The Framework Architecture shall require all systems developed from it to provide facilities that enable their users to control the speed and frequency of information presentation.
1.13.6	The Framework Architecture shall ensure that the safety and security of systems developed from it are not compromised by their ease of use.
2.0	Management Activities - This group contains the activities associated with long term planning, modelling and reporting as well as the maintenance of the infrastructure
2.1	Transport Planning Support
2.1.0.1	The system shall be able to exchange traffic and travel information between adjacent TICs to enhance local information and to improve strategic planning.
2.1.0.2	The system shall be able to provide facilities to enable co-operation and decision making between all relevant authorities (e.g. Ministries, local authorities, police forces etc.) to define optimum traffic management strategies.
2.1.1	Information Management
2.1.1.1	The system shall be able to produce information for travellers on the traffic and travel conditions of all relevant transport modes.
2.1.1.2	The system shall be able to provide links to non-transport information systems using open communication protocols.
2.1.1.3	The system shall be able to collect traffic data for road network use analysis and prediction calculations.
2.1.2	Planning
2.1.2.1	The system shall be able to model the road network for strategic planning calculations.
2.1.2.2	The system shall be able to develop and implement traffic environmental management strategies based on current and predicted traffic conditions.
2.1.2.3	The system shall be able to assist in the planning of (inter-modal) routes.
2.1.2.4	The system shall be able to simulate a demand management strategy on the road network.
2.1.2.5	The system shall be able to simulate potential capacity reduction, e.g. due to road works.
2.1.3	Evaluation
2.1.3.1	The system shall be able to measure the effect of a strategy, and to modify it when necessary.
2.1.4	Reporting

2.1.4.1	The system shall collect and report data as required by legally appointed authorities.
2.1.4.2	The system shall be able to archive (a summary of) historical data on transport demand and transport supply for all transport modes.
2.2	Infrastructure Maintenance Management
2.2.0.1	The system shall provide support for road maintenance and infrastructure management.
2.2.0.2	The system shall be able to recommend short term road maintenance activities, including winter maintenance, based on data collected from the road infrastructure possibly combined with the current and/or forecast weather conditions.
2.2.0.3	The system shall be able to recommend maintenance work schedules such that they cause the minimum disruption to traffic.
2.2.0.4	The system shall be able to support a database of maintenance operations.
2.2.0.5	The system shall be able to transmit current and future maintenance schedules to TCCs.
2.2.0.6	The system shall be able to maintain statistics on road usage to evaluate the need for possible maintenance.
2.2.1	Activation
2.2.1.1	The system shall be able to activate fixed de-icing equipment on parts of the road network.
2.2.2	Monitoring
2.2 2.1	The system shall be able to receive infrastructure equipment status data remotely.
2.2.2.2	The system shall be able to monitor the structural integrity of roads, bridges, tunnels, gantries, etc.
2.2.2.3	The system shall be able to support a database of the road network, infrastructure and road-side equipment.
2.2.3	Maintenance Units
2.2.3.1	The system shall be able to transfer information to, and between, road maintenance units.
2.2.4	Contracts
2.2.4.1	The system shall be able to support the management and control of maintenance contracts.
3.0	Policing/Enforcing - This group contains the activities associated with the enforcement of traffic laws and regulations, and the collection of evidence
3.1	Policing/Enforcing Traffic Regulations
3.1.0.1	The system shall enforce the traffic laws and regulations of the region automatically (where possible).
3.1.0.2	The system shall be able to collect the evidence of a violation of the traffic laws and regulations in a manner suitable to justify the application of a legal punishment
3.1.0.3	The system shall be able to provide support for the enforcement of safe behaviour and vehicle priorities.
3.1.0.4	The system shall not obstruct or slow down traffic in any way, except when it is part of access control.
3.1.0.5	The system shall be able to communicate with Police Command and Control Systems.
3.1.1	Evidence Collection
3.1.1.1	The system shall be able to collect evidence on vehicles that commit traffic signal violations.
3.1.1.2	The system shall be able to collect evidence on vehicles that exceed a local (variable) speed limit.
3.1.1.3	The system shall be able to measure the characteristics, e.g. length, weight etc., of a vehicle automatically, whilst the vehicle is in motion (Weigh in Motion).
3.1.1.4	The system shall be able to identify the cargo being carried by a heavy goods vehicle automatically.
4.0	Financial Transactions - This group contains the activities associated with the payment for traffic or travel services, and includes the manner of the transaction, its enforcement, and the sharing of revenues
4.1	Electronic Financial Transactions
4.1.0.1	The system shall be able to use a variety of relevant payment methods either electronic or not, including central account and post payment, central account and prepayment, on-board account etc.
4.1.0.2	The system shall manage customer data (identification, account, rights of residents, etc.).
4.1.0.3	The system shall give exact details of any financial transaction to the traveller.
4.1.0.4	The system shall be able to manage tariff policies (define fares/fees according to selected criteria).
4.1.1	Traffic Management
4.1.1.1	The system shall have a minimum impact on the traffic flow, e.g. a short transaction duration.
4.1.1.2	The system shall have a minimum impact on the driving task.
4.1.1.3	The system shall not do anything to reduce the safety of either the travellers in the vehicle, or the staff close to the equipment, e.g. in toll booths.
4.1.2	Revenue Sharing
4.1.2.1	The system shall be able to share revenues between road network operators.

4.1.2.2	The system shall enable a single payment to be paid for services offered by different related transport systems (e.g. metro, bus, train, road and parking).
4.1.3	Transaction
4.1.3.1	The system shall be able to exchange information between a toll collection unit and a vehicle.
4.1.3.2	The system shall make atomic electronic financial transactions, I.e. that are never partially complete whatever the circumstances, even in degraded system modes.
4.1.3.3	The system shall have the maximum security necessary for electronic financial transactions.
4.1.3.4	The system shall have a low number of incorrect transactions (e.g., non-effective transactions < 1 in 10E-6; erroneous transactions < 1 in 10E-8);
4.1.4	Enforcement
4.1.4.1	The system shall be able to be able to collect evidence on the non-payment of tolls, and other illegal financial transactions.
5.0	Emergency Services - This group contains `May Day' and stolen vehicle management, the prioritising of emergency vehicles, and hazardous goods incident management
5.1	Emergency Notification and Personal Security
5.1.0.1	The system shall be able to make a `May Day' call.
5.1.0.2	The system shall be able to detect that the vehicle has been involved in an accident, identify its location, and initiate a `May Day' call automatically.
5.1.0.3	The system shall be able to identify the vehicle location, and make a `May Day' call on the command of a vehicle occupant.
5.1.0.4	The system shall be able to give the driver an immediate acknowledgement to his/her emergency call.
5.1.0.5	The system shall be able to identify the driver / vehicle making an emergency call.
5.1.0.6	The system shall be able to provide two-way data and/or voice communications between the vehicle and the emergency control centre.
5.1.0.7	The system shall be able to send a `May Day' call if a critical vehicle component goes into an unsafe condition, or some other emergency is detected.
5.1.0.8	The system shall be able to minimise the response time for rescuing drivers who have requested assistance from the emergency services (breakdown, medical emergency, accident etc.).
5.1.1	Stolen Vehicles
5.1.1.1	The system shall be able to detect when a vehicle is (about to) be driven by an unauthorised person (i.e. stolen)
5.1.1.2	The system shall be able to detect a vehicle when it has been stolen.
5.1.1.3	The system shall be able to stop a vehicle when it has been stolen.
5.2	Emergency Vehicle Management
5.2.0.1	The system shall support a green wave for emergency vehicles.
5.2.0.2	The system shall inform the TCC about the route that is intended for each green wave before it is used.
5.2.0.3	The system shall provide the identity of each traffic signal at which priority is needed, and the `timing window' in which priority is to be given.
5.2.0.4	The system shall receive an indication from the emergency vehicle of its need to be given priority at each set of traffic signals before its arrival in the immediate vicinity.
5.2.0.5	The system shall enable emergency vehicles to pass through the road network without any priority at signalised junctions, e.g. during a return from an incident.
5.3	Hazardous Materials and Incident Notification
5.3.0.1	The system shall monitor the movements of hazardous goods, and provide appropriate support in the case of an incident.
5.3.0.2	The system shall be able to monitor the location of hazardous goods.
5.3.0.3	The system shall be able to receive data on the status, character and quantity of hazardous cargo on vehicles within a pre-defined area of interest, and check compliance with the relevant regulations.
5.3.1	Incident Management
5.3.1.1	The system shall be able to detect that the vehicle has been involved in an accident, identify its location and cargo, and generate an emergency alert automatically.
5.3.1.2	The system shall be able to identify its location and cargo, and generate an emergency alert on the command of the vehicle driver.
5.3.1.3	The system shall be able to advise the emergency services on any hazardous goods that have been involved in an incident.

5.3.1.4	The system shall be able to provide relevant information to the emergency services on the type of hazardous good(s) involved in an incident.
5.3.1.5	Systems shall exchange information on hazardous goods in a manner that is understood by all parties.
5.3.2	Planning
5.3.2.1	The system shall be able to support the planning (e.g. routes) and execution (e.g. authorisation) of the movement of hazardous goods.
6.0	Travel Information - This group contains all the activities concerned with the handling of pre-trip and on-trip information, including mode choice and change, and route guidance
6.1	Pre-trip Information
6.1.0.1	The system shall provide emergency, or urgent, information to all road users free of charge.
6.1.0.2	The system shall be able to require payment for non-emergency, or non-urgent, information.
6.1.0.3	The system shall be able to provide accurate, credible, timely, and easy to comprehend traffic and travel information where it may be of benefit to the user.
6.1.0.4	The system shall be able to provide information on alternative routes where they are quicker, cheaper, shorter, scenic, etc.
6.1.0.5	The system shall enable travellers to plan their trip using their own travel criteria (modes of transport, time of departure/arrival, road selection criteria, etc.).
6.1.1	Modal Choice
6.1.1.1	The system shall be able to influence modal shifts according to a specified transport policy.
6.1.1.2	The system shall be able to provide trip information on other modes of transport for demand-spreading, or when major events occur due to weather conditions, strikes, cultural or sports events etc.
6.1.1.3	The system shall be able to provide current and forecast traffic and travel information at local, regional, national and international levels.
6.1.1.4	The system shall be able to provide trip information that may include prices, fares, routes, incidents, roadworks, forecast & current traffic situations, traffic control, demand mgt measures, local warnings, special events, weather conditions, hotels etc.
6.1.2	Information Handling
6.1.2.1	The system shall inform the User when changes occur to the criteria upon which the pre trip information had been given.
6.1.2.2	The system shall be able to provide information on the cancellation of departures from a railway station, an airport, a port or a coach station (due to the weather; strikes or other reasons).
6.1.2.3	The system shall be able to provide information to all drivers including route restrictions, travel times, etc.
6.1.2.4	The system shall be able to support a database of events with links between events that occur concurrently and at the same or adjacent locations.
6.1.2.5	The system shall be able to analyse, process and retrieve data from different combinations of sources (including floating car).
6.1.2.6	The system shall be able to provide road and traffic information adapted to different classes of users, e.g. travellers, radio broadcasters, service operators.
6.1.2.7	The system shall provide information using graphical representation or text. Graphical form shall include the use of maps as well as text.
6.1.2.8	The system shall provide information in the native language at the output location, and/or from a user selected choice of other appropriate foreign languages.
6.1.2.9	The system shall provide Information Management tools for the operator.
6.1.3	Traveller Interaction
6.1.3.1	The system shall be able to provide facilities for the necessary user identification when a traveller requests information that may result in the purchase or booking of services.
6.1.3.2	The system shall be able to require payment for one-off usage of the service.
6.1.3.3	The system shall enable the traveller to use cash or electronic means to pay for the one-off usage of the service, where appropriate.
6.1.3.4	The system shall be able to provide access to reservations and pre-payment services.
6.1.3.5	The system shall be able to provide booking & pre-payment services from all places that provide route planning information (including railway stations, airports, ports etc.).
6.1.3.6	The system shall enable a traveller to book a parking space at Park and Ride sites as part of a trip.
6.1.3.7	The system shall provide information via (public) terminals located at strategic locations: e.g. home, office, bus station, railway, metro station, vehicle, restaurant, etc.

6.1.3.8	The system shall be able to provide customised pre-trip information to hand-held and in-vehicle devices.
6.1.3.9	The system shall communicate with other information systems using open standard protocols.
6.1.3.10	The system shall provide information for fixed and mobile terminals using open standard communication protocols.
6.2	On-trip Driver Information
6.2.0.1	The system shall provide emergency, or urgent, information to all road users free of charge.
6.2.0.2	The system shall be able to require payment for non-emergency, or non-urgent, information.
6.2.0.3	The system shall be able to be activated automatically by another system, e.g. traffic management.
6.2.0.4	The system shall provide traffic information to the traveller during his/her trip in a timely manner, and include travel conditions, accidents, special events, car park status, etc.
6.2.0.5	The system shall be able to provide urban and inter-urban traffic and travel information to drivers about the domain they are not currently in.
6.2.0.6	The system shall inform the User when changes occur to the criteria upon which the pre trip information had been given.
6.2.1	Mode Change
6.2.1.1	The system shall be able to provide alternative routes or mode-switch recommendations when it detects, or is informed, that road network problems have occurred.
6.2.1.2	The system shall be able to display alternative routes or modes at modal interchange points, or at places where tourism information is available.
6.2.1.3	The system shall be able to provide information about other transport modes: e.g. location of P&R, PT timetable, etc.
6.2.2	Information Handling
6.2.2.1	The system shall be able to inform travellers on the current average travel time between fixed points.
6.2.2.2	The system shall be able to provide real-time P&R and PT information to vehicle drivers.
6.2.2.3	The system shall be able to provide cyclists and pedestrians with information about suitable routes.
6.2.2.4	The system shall provide road and traffic safety advice based on current weather and traffic conditions.
6.2.2.5	The system shall be able to provide information to all drivers including route restrictions, travel times, etc.
6.2.2.6	The system shall be able to provide routing information for Commercial traffic to/from a (cargo) modal interchange.
6.2.2.7	The system shall be able to support a database of events with links between events that occur concurrently and at the same or adjacent locations.
6.2.2.8	The system shall be able to provide road information according to different geographic scales, e.g. local, regional, national, international.
6.2.2.9	The system shall be able to adapt the information to different classes of users, e.g. travellers, radio broadcasters, service operators.
6.2.2.10	The system shall be able to collect data from a variety of different sources, including road/traffic management, police, weather services, floating car etc.).
6.2.2.11	The system shall be able to provide operators with an overall view of all active events in an area.
6.2.2.12	The system shall provide Information Management tools for the operator.
6.2.3	Traveller Interaction
6.2.3.1	The system within the vehicle, or in the centre, shall support various types of presentation to the user.
6.2.3.2	The system shall normally provide messages from a finite set of well defined messages.
6.2.3.3	The system shall provide information in the native language at the output location, and/or from a user selected choice of other appropriate foreign languages, when applicable.
6.2.3.4	The system shall provide information using open standard communication protocols.
6.2.3.5	The system shall be able to provide customised on-trip information to hand-held and in-vehicle devices.
6.2.3.6	The system shall enable drivers to customise the style and content of the information that they receive from hand-held and in-vehicle devices.
6.2.3.7	The system shall be able to retain the customisation details in a manner that is independent of any physical output device.
6.2.3.8	The system shall be able to provide road and traffic information using road-side equipment, e.g. VMS.
6.2.3.9	The system shall be able to provide in-vehicle road, traffic, route guidance and parking information via locally sited equipment, e.g. beacon.

6.3	Personal Information Services This is a special case of Groups 6.1, 6.2, 6.4 and 10.4 (ISO Services 1, 2, 3 and 5)
6.4	Route Guidance and Navigation
6.4.0.1	The system shall provide travellers with recommended routes to specified destinations.
6.4.0.2	The system shall not base its decisions on a restricted sub-set of information about the road network.
6.4.0.3	The system shall know where it is within the road network.
6.4.0.4	The system shall be able to modify its navigation instructions if an incorrect turn is made.
6.4.1	Information Handling
6.4.1.1	The system shall be able to provide guidance to Car Parks (with parking spaces).
6.4.1.2	The system shall be able to use real-time information to compute the recommended route.
6.4.1.3	The system shall be able to compute the total predicted journey time over the route selected.
6.4.1.4	The system shall be able provide customised navigation information to the destination using a variety of selection criteria.
6.4.1.5	The system shall be able to provide guidance to Points of Interest.
6.4.1.6	The system shall provide information which is consistent with any other information being presented about the road.
6.4.2	Traveller Interaction
6.4.2.1	The system shall provide route guidance using visual and voice instructions.
6.4.2.2	The system shall contain menus which are structured in a logical manner and oriented towards the requirements of the driver (e.g. the most frequently used function shall be the easiest to select).
6.4.2.3	The system shall enable bi-directional voice and data communication with the vehicle.
6.4.2.4	The system shall enable the use of portable equipment to provide route guidance.
7.0	Traffic Management - The activities associated with traffic control, incident management and demand management, including monitoring, planning, flow control, exceptions management, speed management, lane and parking management, HOV, road pricing and zoning, and VRUs
7.1	Traffic Control
7.1.0.1	The system shall support the existing and new traffic management needs of authorities by providing a flexible yet comprehensive approach to determine traffic management strategies (including bridge and tunnel control).
7.1.0.2	The system shall be able to implement identified control strategies that conform with specified policy.
7.1.0.3	The system shall not do anything to reduce road safety.
7.1.0.4	The system shall manage road traffic in such a way that levels of environmental (i.e. atmospheric and noise) pollution may be reduced.
7.1.0.5	The system shall manage road traffic in such a way that congestion (travel time) may be reduced.
7.1.0.6	The system shall be able to help co-ordinate the activities of TICs and TCCs.
7.1.0.7	The system shall be able to exchange information between TICs and TCCs, including across national boundaries.
7.1.0.8	The system shall enable the data that it stores to be extracted by an operator onto a variety of media and used for other purposes, or by other organisations.
7.1.0.9	The system shall ensure that traveller information service providers are aware of the traffic management strategy, so that they can provide information that conforms to it.
7.1.0.10	The system shall be able to control urban roads and traffic.
7.1.0.11	The system shall be able to control inter-urban roads and traffic.
7.1.0.12	The system shall be able to use different methodologies to control separate areas of the road network.
7.1.0.13	The system shall be able to manage the urban/inter-urban interface.
7.1.1	Monitoring
7.1.1.1	The system shall be able to monitor sections of the road network to provide the current traffic conditions (e.g. flows, occupancies, speed and travel times etc.) as real time data.
7.1.1.2	The system shall monitor urban roads and traffic.
7.1.1.3	The system shall monitor inter-urban roads and traffic.
7.1.1.4	The system shall be able to monitor traffic flow at, and the operation of, the road intersections of the network over which it has the control.
7.1.1.5	The system shall be able to monitor the entire road network (network state surveillance tool).
7.1.1.6	The system shall be able to monitor and record weather conditions (wind, fog, rain level, ice, etc.).
7.1.1.7	The system shall be able to monitor and record environmental (atmospheric and noise) pollution conditions, and provide an alarm when a certain threshold is exceeded.

7.1.1.8	The system shall be able to measure the range of visibility and detect reductions caused by adverse weather and pollution conditions (but not darkness).
7.1.2	Planning
7.1.2.1	The system shall be able to use consistent historical data to complement real-time data, when necessary.
7.1.2.2	The system shall be able to predict short, medium, and long-term traffic conditions.
7.1.2.3	The system shall be able to use historical data to complement predicted data, when necessary.
7.1.2.4	The system shall be able to analyse road and traffic data to predict possible critical situations.
7.1.2.5	The system shall be able to predict weather conditions, in particular the formation of fog and/or ice.
7.1.2.6	The system shall be able to predict short, medium and long-term road travel produced environmental (atmospheric and noise) pollution conditions based on traffic and weather conditions.
7.1.2.7	The system shall be able to provide historical and predicted data.
7.1.3	Traffic Control Centres
7.1.3.1	The system shall enable a TCC operator to control, possibly remotely, infrastructure elements (e.g. traffic lights, VMS).
7.1.3.2	The system shall enable a TCC operator to log all significant events and to record free text messages prior to their output to travellers.
7.1.3.3	The system shall be able to provide a graphical representation of the road network (including equipment, events, traffic condition etc.) to TCC operators.
7.1.3.4	The system shall be able to activate control devices (e.g. traffic lights, VMS), either individually or in groups.
7.1.3.5	The system shall enable TCC operators to make temporary changes to the normal control strategy in real-time.
7.1.3.6	The system shall be able to implement planned control strategies for planned events (e.g. sport, cultural, etc.).
7.1.3.7	The system shall be able to support a database of all known (future) events.
7.1.4	Traffic Flow Control
7.1.4.1	The system shall be able to control the entries and exits to motorways.
7.1.4.2	The system shall be able to provide ramp metering (e.g. using traffic signals or barriers) at selected locations (e.g. slip road entrances to high speed roads).
7.1.4.3	The system shall provide Tidal Flow Control (reservation of lanes for exclusive use in one direction for a period, then the other direction for another period, on parts of the road network).
7.1.4.4	The system shall be able to provide advice to drivers as they approach car parks (on-street and off-street, as well as motorway service area parking).
7.1.4.5	The system shall be able to provide priority to selected travellers (e.g. PT, emergency vehicles, cycles, pedestrians) through the road network, including on motorways (when applicable).
7.1.4.6	The system shall be able to provide control measures for bridges so that warnings of weather conditions, vehicle restrictions and closure can be provided.
7.1.4.7	The system shall be able to provide control measures for tunnel environments i.e. vehicle restrictions, fire detection, atmospheric pollution and closure.
7.1.4.8	The system shall be able to provide coordinated traffic management operations during periods of mass movement across (many) regions.
7.1.4.9	The system shall be able to provide specific traffic management for exceptional vehicles (e.g. very dangerous cargo, wide loads, etc.).
7.1.5	Exceptions Management
7.1.5.1	The system shall be able to provide control measures to protect road maintenance work and workers.
7.1.5.2	The system shall be able to command drivers to change lanes on multi-lane roads.
7.1.5.3	The system shall be able to change the direction of traffic flow on a carriageway in an orderly manner so that it does not create a safety hazard to any road user.
7.1.5.4	The system shall be able to reverse the direction of traffic flow on parts of the urban network.
7.1.5.5	The system shall be able to close roads and advise drivers of a suitable diversionary route for a period of time.
7.1.5.6	The system shall be able to command certain classes of vehicle (e.g. heavy vehicles or tourist traffic) to take an alternative route for a period of time.
7.1.5.7	The system shall be able to recommend re-routing strategies to reduce congestion or atmospheric pollution.

7.1.5.8	The system shall request confirmation of all exceptional measures before they are executed.
7.1.6	O/D Computations
7.1.6.1	The system shall be able to provide Origin/Destination computations, and route assignment estimations, for the road network.
7.1.7	Speed Management
7.1.7.1	The system shall be able to show the maximum authorised speed of vehicles on selected carriageways to be shown to drivers, and to detect violators.
7.1.7.2	The system shall be able to set variable speed limits on parts of the road network.
7.1.7.3	The system shall be able to calculate recommended speed limits for given traffic and weather conditions, and road network characteristics.
7.1.7.4	The system shall transmit recommended speed limits to equipped vehicles.
7.1.7.5	The system shall be able to support a database of all speed limits on the road network.
7.1.7.6	The system shall be able to support an in-vehicle database of road network data (e.g. speed limits, road hazards, junctions etc.).
7.1.8	Roadside-Vehicle Communications
7.1.8.1	The system shall be able to transmit information to a vehicle to update its on-board database.
7.1.9	Adaptive Traffic Control
7.1.9.1	The system shall be able to provide green wave management for all vehicles.
7.1.9.2	The system shall be able to minimise delays of all vehicles using adaptive signal control
7.1.9.3	The system shall be able to grant priority to selected vehicles (e.g. PT, emergency vehicles) at an intersection controlled by some form of traffic signals.
7.1.9.4	The system shall be able to give priority to PT in a manner that minimises the impact on other road users.
7.1.10	Lane Management
7.1.10.1	The system shall be able to reserve certain traffic lanes exclusively to specific classes of vehicles (e.g. high occupancy vehicles, or buses) and to detect violators.
7.1.11	Parking Management
7.1.11.1	The system shall be able to monitor the current usage of the parking facilities.
7.1.11.2	The system shall be able to forecast the need for parking slots.
7.1.12	Vulnerable Road Users
7.1.12.1	The system shall be able to control pedestrian and cycle crossings.
7.1.12.2	The system shall be able to monitor and control pedestrian and cycle crossings in order to optimise their use.
7.2	Incident Management
7.2.0.1	The system shall detect and respond to various incidents on the road network.
7.2.0.2	The system shall not do anything to reduce road safety.
7.2.0.3	The system shall not do anything that might aggravate, or cause, an incident.
7.2.0.4	The system shall assist the emergency services to provide an effective response to road traffic incidents.
7.2.0.5	The system shall collect and filter emergency calls from travellers in the road network using a variety of types of communication (e.g. road-side telephones, mobile phones, (automatic) on-board 'MayDay' etc.)
7.2.0.6	The system shall minimise the time between the occurrence of an incident and its detection.
7.2.0.7	The system shall be able to validate that an incident has occurred in order to minimise false alarms.
7.2.0.8	The system shall be able to suggest one or more responses for dealing with an incident.
7.2.0.9	The system shall be able to run (pre-)defined incident mitigation strategies automatically.
7.2.1	Emergency Services
7.2.1.1	The system shall be able to locate and identify emergency vehicles on the road network.
7.2.1.2	The system shall be able to co-ordinate the emergency and rescue services once an incident has been detected, until all injured persons have reached a hospital.
7.2.1.3	The system shall provide communications between the emergency services, hospitals and TCCs for the provision of incident information.
7.2.2	Information Management
7.2.2.1	The system shall be able to collect and store data on each incident, e.g. location, type, severity, number & type of vehicles involved, the emergency/rescue vehicles needed etc.
7.2.2.2	The system shall be able to identify and classify all incidents on the road network.

7.2.2.3	The system shall be able to provide information on each incident to TICs for onward transmission to travellers.
7.2.3	Reporting
7.2.3.1	The system shall be able to produce incident data statistics, e.g. frequencies of occurrence, by time, type and location; identification of high risk locations on the road network; performance of the incident detection system.
7.2.4	Post-Incident Management
7.2.4.1	The system shall be able to minimise the consequences of an incident on the road network for those travellers who are not involved.
7.2.4.2	The system shall be able to monitor the aftermath of an incident.
7.2.5	Pre-Incident Management
7.2.5.1	The system shall be able to detect non-vehicle incidents before they can escalate into traffic accidents, e.g. bad weather conditions, objects on the road, ghost drivers, etc.
7.2.5.2	The system shall be able to provide local warnings on dangerous sections of the road network.
7.2.6	Hazardous Goods
7.2.6.1	The system shall be able to advise the emergency services on any hazardous goods that have been involved in an incident.
7.3	Demand Management
7.3.0.1	The system shall provide information that will influence travellers' decisions regarding their destinations, time, mode of travel, route etc.
7.3.0.2	The system shall receive up-to-date information on those factors that will influence the demand management strategy, e.g. traffic levels, car park usage, PT usage, fares, tolls, etc.
7.3.0.3	The system shall be able to recommend a strategy to reduce demand.
7.3.0.4	The system shall be able to simulate a demand management strategy on the road network.
7.3.0.5	The system shall be able to simulate potential capacity reduction, e.g. due to road works.
7.3.1	Zoning
7.3.1.1	The system shall be able to create a traffic collar and limit the entry of all vehicles into a defined area according to (a set of) criteria.
7.3.1.2	The system shall be able to recommend alternative routes that take into account the needs of heavy vehicles (and hazardous goods).
7.3.1.3	The system shall be able to control the access of vehicles into a zone using a form of identification, e.g. electronic tags, number plate readers, etc.
7.3.1.4	The system shall be able to use physical barriers to control the access of vehicles into a zone.
7.3.1	Pricing Management
7.3.1.1	The system shall be able charge for the use of a section of road, or a bridge, tunnel etc., based on given policy decisions (i.e. road pricing)
7.3.1.2	The system shall be able to adjust toll fees according to a given pricing strategy.
7.3.1.3	The system shall be able to adjust parking fees according to a given pricing strategy.
7.3.1.4	The system shall be able to adjust public transport fares according to a given pricing strategy.
7.3.2	Parking Management
7.3.2.1	The system shall be able to implement parking strategies in specific areas, including P&R strategies.
7.3.3	Vulnerable Road Users
7.3.3.1	The system shall be able to provide information to promote the use of cycles and walking.
7.3.4	Car Sharing
7.3.4.1	The system shall be able to provide information so that travellers may share a vehicle with others for all or part of a journey.
7.4	Safety Enhancements for Vulnerable Road Users These are covered in Group 7.1 (ISO Service 7)
7.5	Intelligent Junctions and Links. No EU User Need identified.
8.0	In-Vehicle Systems - This group contains the functions found within a vehicle, including vision enhancement, longitudinal and lateral collision avoidance, lane keeping, platooning, speed control, driver alertness, 'May Day' initiation, etc.
8.1	Vision Enhancement
8.1.0.1	The system shall be able to measure the visibility distance and detect reductions caused by adverse weather and pollution conditions (but not darkness) of the view seen by the driver.
8.1.0.2	The system shall be able to enhance the vision of the driver in adverse visibility conditions, e.g. in fog, darkness etc.

8.1.0.3	The system shall present vision enhancement information in a manner that is easy for the driver to assimilate into whatever can actually be seen at the time.
8.1.0.4	The system shall present vision enhancement information in a manner that does not interfere with the driver's vision in normal lighting conditions.
8.2	Automated Vehicle Operation
8.2.0.1	The system shall provide direct or indirect assistance for the driving task.
8.2.1	Collision Avoidance
8.2.1.1	The system shall be able to detect when the host vehicle is too close to the vehicle in front.
8.2.1.2	The system shall be able to keep the host vehicle a certain distance behind the vehicle in front (autonomous cruise control).
8.2.1.3	The system shall be able to control the longitudinal dynamic behaviour of the host vehicle automatically
8.2.2	Lane Keeping
8.2.2.1	The system shall be able to control the lateral dynamic behaviour of the vehicle automatically, and keep the vehicle within its current lane of the carriageway.
8.2.2.2	The system shall be able to provide the driver with information, or active steering support, to assist him/her to keep within the current lane of the carriageway.
8.2.3	Platooning
8.2.3.1	The system shall be able to create a platoon of vehicles, in particular trucks (Electronic Towbar or Road Train).
8.2.3.2	The system shall enable the leading vehicle of a platoon to supervise and manage the operation and tracking of the following vehicle(s).
8.2.3.3	The system shall enable the following vehicle(s) in a platoon to perform all normal driving manoeuvres without any host driver intervention.
8.2.3.4	The system shall enable equipped vehicles to leave or join the back of the platoon at any speed.
8.2.3.5	The system shall allow the following vehicles to perform conventional operations that do not interfere with their tracking of the leading vehicle.
8.2.3.6	The system shall enable the following vehicles in a platoon to monitor their surroundings and to perform emergency operations in critical situations.
8.2.3.7	The system shall enable the vehicles in a platoon to be closer together than when manually controlled.
8.2.4	Short Range Communications
8.2.4.1	The system shall be able to communicate with other equipped vehicles, and/or the infrastructure, to exchange data for automatic vehicle control.
8.2.5	Speed Control
8.2.5.1	The system shall be able to limit the speed of a vehicle automatically to the a given, but variable, maximum (intelligent speed adaptation)
8.2.5.2	The system shall be able to receive mandatory speed limits from outside the vehicle (and store them within the vehicle).
8.2.5.3	The system shall be able to support a database of default speed limits and other road hazards.
8.2.5.4	The system shall be able to display continuously to the driver the current mandatory speed limit.
8.2.5.5	The system shall be able to offer the driver the ability to keep the vehicle below a new mandatory speed limit automatically (manual intelligent speed control).
8.2.5.6	The system shall be able to receive recommended or mandatory speeds from outside the vehicle.
8.2.6	Supporting Tasks
8.2.6.1	The system shall be able to control the brakes of the vehicle automatically.
8.2.6.2	The system shall be able to control the engine of the vehicle automatically.
8.2.6.3	The system shall be able to monitor the road and the vehicles in the immediate vicinity.
8.2.6.4	The system shall be able to monitor the course of the host vehicle.
8.2.6.5	The system shall be able to control the vehicle dynamics automatically.
8.2.6.6	The system shall be able to measure the distance to the vehicle in front.
8.2.6.7	The system shall be able to control the steering of the vehicle automatically.
8.3	Longitudinal Collision Avoidance
8.3.0.1	The system shall be able to provide the driver with assistance in longitudinal separation from other vehicles in, or entering, the host vehicle's lane.
8.3.0.2	The system shall be able to monitor the conflict zone and predict the trajectory of other vehicles relative to the host vehicle, or the vehicle's movement relative to adjacent stationary objects.

8.3.0.3	The system shall be able to support a database of safety margins for distances between the vehicle and all other adjacent objects.
8.3.1	Collision Avoidance
8.3.1.1	The system shall be able to keep the host vehicle a certain distance behind the vehicle in front (autonomous cruise control).
8.3.1.2	The system shall be able to warn the driver when the vehicle in front is too close.
8.3.1.3	The system shall be able to determine a safe vehicle trajectory relative to the lane/road boundaries.
8.3.1.4	The system shall be able to warn the driver of possible critical situations using audible, visual or haptic (physical feedback to the driver) methods.
8.3.1.5	The system shall be able to control the vehicle automatically for a short period of time when an impending collision has been detected.
8.3.1.6	The system shall be able to change the motion of the vehicle automatically to stabilise the situation when intervention is imperative.
8.3.2	Supporting Tasks
8.3.2.1	The system shall be able to detect the position of neighbouring vehicles (and objects).
8.3.2.2	The system shall be able to measure the distance to the vehicle in front.
8.3.2.3	The system shall be able to control the brakes of the vehicle automatically.
8.3.2.4	The system shall be able to control the engine of the vehicle automatically.
8.3.2.5	The system shall be able to control the vehicle dynamics automatically.
8.4	Lateral Collision Avoidance
8.4.0.1	The system shall monitor for hazards involved in lane keeping, lane changing, entering and leaving high speed roads, and overtaking.
8.4.0.2	The system shall be able to monitor the conflict zone and predict the trajectory of other vehicles relative to the host vehicle, or the vehicle's movement relative to adjacent stationary objects.
8.4.1	Collision Avoidance
8.4.1.1	The system shall be able to warn the driver if the host vehicle moves towards a volume of road space that is about to be occupied, or already occupied, by another road user.
8.4.1.2	The system shall be able to support a database of safety margins for distances between the vehicle and all other adjacent objects.
8.4.1.3	The system shall be able to determine a safe vehicle trajectory relative to the lane/road boundaries.
8.4.1.4	The system shall be able to control the vehicle automatically for a short period of time when an impending side collision has been detected.
8.4.2	Lane Keeping
8.4.2.1	The system shall be able detect the position of the vehicle relative to lane boundaries and/or roadway shoulders.
8.4.2.2	The system shall be able to warn the driver when the vehicle approaches or exceeds the lane boundaries.
8.4.3	Supporting Tasks
8.4.3.1	The system shall be able to detect the position of neighbouring vehicles (and objects).
8.4.3.2	The system shall be able to control the steering of the vehicle automatically.
8.4.3.3	The system shall be able to control the brakes of the vehicle automatically.
8.4.3.4	The system shall be able to control the engine of the vehicle automatically.
8.4.3.5	The system shall be able to control the vehicle dynamics automatically.
8.5	Safety Readiness
8.5.0.1	The system shall minimise the risk of an accident due to the impaired alertness of the driver.
8.5.0.2	The system shall be able to detect impairment of the driver, e.g. alcohol/drug abuse, drowsiness, sudden health problems, prolonged inattention, etc.
8.5.0.3	The system shall be able to warn the driver when a lack of alertness is detected.
8.5.0.4	The system shall be able to warn surrounding drivers that this driver has a problem.
8.5.1	May Day
8.5.1.1	The system shall be able to make a `May Day' call.
8.5.1.2	The system shall be able to detect that the vehicle has been involved in an accident, identify its location, and initiate a `May Day' call automatically.
8.5.1.3	The system shall be able to identify the vehicle's location, and make a `May Day' call on the command of a vehicle occupant.
8.5.2	Automatic Parking

8.5.2.1	The system shall be able to manoeuvre the vehicle to the roadside automatically, when the driver does not respond.
8.5.3	Environmental Monitoring
8.5.3.1	The system shall be able to measure and analyse the road surface (e.g. for black ice) together with the vehicle dynamic characteristics, and alert the driver (and/or control the dynamics of the vehicle automatically when necessary)+G465.
8.5.3.2	The system shall be able to provide information on the current range of visibility, and to recommend an appropriate speed.
8.5.3.3	The system shall be able to detect the presence of vulnerable road users (VRU), e.g. pedestrians, cyclists, animals, etc.
8.5.4	Accident Data Recording
8.5.4.1	The system shall be able to record data about an accident and the journey immediately before (black box).
8.6	Pre-crash Restraint Deployment
8.6.0.1	The system shall be able to detect the imminence of a longitudinal collision.
8.6.0.2	The system shall be able to detect the imminence of a lateral collision.
9.0	Freight and Fleet Operations - This group contains all the activities associated with FFM, including statutory data collection and reporting; orders and document mgt; planning, scheduling, monitoring, reporting & operations mgt; vehicle and cargo safety; mgt of inter-modal interfaces.
9.1	Commercial Vehicle Pre-Clearance
9.1.0.1	The system shall enable the device storing the information recorded by the tachograph to be physically removed from the vehicle.
9.1.0.2	The system shall enable all information stored on-board the vehicle to be interrogated whenever required.
9.1.0.3	The system shall be able to communicate with road-side equipment whilst the vehicle is travelling at normal speed.
9.1.0.4	The system shall protect the tachograph against fraud, and from being accessed by unauthorised persons.
9.2	Commercial Vehicle Administrative Processes
9.2.0.1	The system shall be able to store all necessary statutory information on-board the vehicle.
9.2.0.2	The system shall be able to provide communications between fleet operators and the relevant authorities for the transfer of registration data and payments.
9.3	Automated Roadside Safety Inspection
9.3.0.1	The system shall be able to transfer safety-related information (e.g. brakes status, driving time etc.) from the vehicle to the road-side whilst the vehicle is travelling at normal speed.
9.3.0.2	The system shall enable the weight of a commercial vehicle to be measured whilst the vehicle is travelling (weigh-in-motion).
9.3.0.3	The system shall be able to collect evidence automatically about a vehicle that has violated the regulations.
9.4	Commercial Vehicle On-Board Safety Monitoring
9.4.0.1	The system shall be able to monitor the vehicle and cargo safety status, and the behaviour of the driver (e.g. duration of driving time, excess speed).
9.4.0.2	The system shall issue a warning to the driver whenever a threshold for a vehicle or cargo safety status, or driver behaviour, has been exceeded, and the relevant data shall be recorded.
9.4.0.3	The system shall be able to identify the vehicle's location, and make a `May Day' call to the emergency services on the command of a vehicle occupant.
9.4.0.4	The system shall be able to detect that the vehicle has been involved in an incident, identify its location, and initiate a `May Day' call to the emergency services automatically.
9.5	Commercial Fleet Management
9.5.0.1	The system shall support fleet and freight operations for all sizes of operator, including single vehicle companies.
9.5.0.2	The system shall be able to validate compliance with global regulations.
9.5.1	Road Freight Management
9.5.1.1	The system shall enable the exchange of information, e.g. market enquiries, offer and supplier evaluation data, contracts, invoices, payments etc. between customers and suppliers.

9.5.1.2	The system shall be able to provide information about a cargo, e.g. loading status, contents, delays, delivery status, disputes etc. to the fleet management centre in real time.
9.5.1.3	The system shall be able to prepare and update official documents, e.g. transport orders, customs declarations, hazardous goods declarations, notices of dispatch etc. in a controlled manner, and assist the process of checking them.
9.5.1.4	The system shall be able to transfer official documents, e.g. transport orders, customs declarations, hazardous goods declarations, notices of dispatch etc. between vehicles, the fleet management centre and the relevant authorities in a controlled manner.
9.5.1.5	The system shall be able to transfer any necessary information about an operation, e.g. route, (hazardous or oversize) cargo, etc. to the relevant authorities, e.g. TCCs, TICs etc.
9.5.1.6	The system shall be able to track the physical and administrative status of a cargo throughout its journey.
9.5.1.7	The system shall enable the consignee to receive information, e.g. delivery note, invoice etc. directly from the vehicle.
9.5.1.8	The system shall enable the shipper to receive information, e.g. destination, contractual data etc. directly from the vehicle.
9.5.1.9	The system shall be able to confirm electronic documents with electronic signatures.
9.5.1.10	The system shall be able to reconstitute the route taken by any item, and the contracts that have been fulfilled (tracing function).
9.5.1.11	The system shall be able to analyse the costs and performance of the FFM operations.
9.5.2	Road Freight Fleet Management
9.5.2.1	The system shall be able to support the planning, monitoring, controlling and evaluation of vehicle fleet operations.
9.5.2.2	The system shall be able to assign tasks to vehicles and drivers, e.g. pick-up and delivery instructions.
9.5.2.3	The system shall be to optimise the scheduling of vehicles.
9.5.2.4	The system shall be to optimise the scheduling of drivers.
9.5.2.5	The system shall be able to optimise the assignment of loads.
9.5.2.6	The system shall be able to weigh the vehicle, compare it with the expected weight and report on any discrepancies or overweight.
9.5.2.7	The system shall be able to transfer all documents, task assignment, load planning etc. information to the vehicle.
9.5.2.8	The system shall be able to provide an optimal route for each `normal' vehicle.
9.5.2.9	The system shall be able to provide suitable routes for `abnormal' vehicles, e.g. oversized, overweight, hazardous cargo etc.
9.5.2.10	The system shall be able to predict a time of arrival.
9.5.2.11	The system shall be able to communicate with third party, e.g. workshop, customs, road operator, police, etc.
9.5.2.12	The system shall be able to provide a driver with a suitable alternative route, when the original planned route becomes unavailable.
9.5.2.13	The system shall be able to locate, identify and monitor the status of a vehicle, equipment or cargo at any time.
9.5.2.14	The system shall be able to inform the driver about a change of task, e.g. change of pick-up, delivery, route etc.
9.5.2.15	The system shall be able to schedule the maintenance of vehicles, equipment and cargo units.
9.5.2.16	The system shall be able to monitor and analyse the vehicle fleet and drivers' staff costs and performance.
9.5.3	Road Vehicle, Driver, Equipment and Cargo Management
9.5.3.1	The system shall support the activities associated with the management of individual vehicles.
9.5.3.2	The system shall be able to store all necessary commercial and statutory vehicle, driver, trip and freight information on-board the vehicle.
9.5.3.3	The system shall be able to receive all necessary commercial and statutory vehicle, driver, trip and freight information from the fleet management centre at any time.
9.5.3.4	The system shall be able to transfer official documents, e.g. transport orders, customs declarations, hazardous goods declarations, notices of dispatch etc. between vehicles and relevant parties in a controlled manner.
9.5.3.5	The system shall enable the driver to receive traffic information.

9.5.3.6	The system shall enable the driver to receive weather information.
9.5.3.7	The system shall enable voice communication between a vehicle and the fleet management centre.
9.5.3.8	The system shall be able to assist the process of checking the vehicle, equipment and cargo documents.
9.5.3.9	The system shall be able to record data, e.g. from vehicle, equipment, cargo unit sensors, and driver input etc. for later processing.
9.5.3.10	The system shall be able to record driver's hours, and report on available hours, deviations and disturbances.
9.5.3.11	The system shall enable the driver to receive a change to the route, task, etc. at any time.
9.5.3.12	The system shall be able to record the actual route taken.
9.5.3.13	The system shall be able to report when a substantial deviation from the intended route has been used (e.g. to detect a possible theft of the vehicle).
9.5.3.14	The system shall be able to determine a delay in the planned time of arrival, and communicate this to the fleet management centre.
9.5.3.15	The system shall enable the automatic payment of tolls etc.
9.5.3.16	The system shall be able to detect when the status of the cargo (e.g. changes in temperature or humidity) exceeds a given limit during the transport cycle, and trigger an alarm.
9.5.3.17	The system shall be able to adjust the temperature and humidity of a freight unit remotely, during the transport cycle.
9.5.3.18	The system shall be able to monitor the vehicle and cargo unit for erroneous procedures (e.g. doors being opened incorrectly) and trigger an anti-theft alarm message to the home base and/or any relevant body.
9.5.3.19	The system shall be able to provide communications between the vehicle and local breakdown support, e.g. for repair of punctured tyres.
9.5.3.20	The system shall enable automatic remote vehicle diagnostics.
9.5.3.21	The system shall be able to monitor and analyse the vehicle and driver's staff costs and performance.
9.5.4	Freight Distribution
9.5.4.1	The system shall manage freight and fleets in such a way that the impact of commercial vehicles on the urban environment will be reduced.
9.5.4.2	The system shall be able to manage freight and fleets in such a way that the distribution of goods in an urban area will be optimised.
9.5.4.3	The system shall be able to manage (un-)loading zones to aid the distribution of goods in an urban area.
9.5.4.4	The system shall be able to book places in an equipment/container storage area.
9.5.4.5	The system shall be able to forecast the use of an equipment/container storage area
9.5.5	Inter-Modal Interface
9.5.5.1	The system shall be able to manage the interface between freight transport modes in an effective manner.
9.5.5.2	The system shall be able to support a combined transport interface management function.
9.5.5.3	The system shall be able to support a freight transport order processing function that is common to all modes of transport.
9.5.5.4	The system shall ensure that the information associated with a vehicle, equipment or container is available when that vehicle, equipment or container arrives at a modal interchange.
9.5.5.5	The system shall enable the matching of demand and supply of (multi-modal) freight transport resources.
10.0	Public Transport - This group contains the activities associated with public transport (PT), demand responsive PT, Shared PT, on-trip PT Information and Traveller Security. It includes management, scheduling, monitoring, information handling, communications and PT priority.
10.1	Public Transport Management
10.1.0.1	The system shall provide effective and attractive PT.
10.1.0.2	The system shall be able to manage all modes of PT.
10.1.0.3	The system shall be able to assist PT operators in planning for the optimum use of existing resources to meet the demand.
10.1.0.4	The system shall be able to analyse records of usage and operational data, and passenger surveys, to assist in the planning process.
10.1.1	Scheduling

10.1.1.1	The system shall be able to produce optimum vehicle schedules that include links, points, day types, vehicle types, demand types, time bands, limits based on demand etc.
10.1.1.2	The system shall be able to produce optimum driver schedules.
10.1.2	Monitoring
10.1.2.1	The system shall be able to receive information about the identity, location, status and occupancy all vehicles in the fleet in real time.
10.1.2.2	The system shall be able to monitor the number of travellers waiting at a pick-up point, e.g. Park and Ride site.
10.1.3	Incident Management
10.1.3.1	The system shall be able to identify an incident and make arrangements for the care for the passengers.
10.1.3.2	The system shall be able to schedule PT operations dynamically so that incidents or unexpected events can be handled with the minimum disruption.
10.1.4	Information Handling
10.1.4.1	The system shall be able to inform travellers about PT operations (e.g. travel times, delays, fares etc.).
10.1.4.2	The system shall be able to provide information about PT services to the travellers either on-board the PT vehicle, or before the journey.
10.1.4.3	The system shall be able to provide an update of arrival/departure information in real-time and present it to travellers at PT stops and/or on-board PT vehicles.
10.1.5	Communications
10.1.5.1	The system shall be able to provide two-way data and voice communication between PT vehicles and a central location.
10.1.6	Priority
10.1.6.1	The system shall be able to select those vehicles that need to be given priority and communicate the requests to the TCC.
10.2	Demand Responsive Public Transport
10.2.0.1	The system shall be able to provide both planned and spontaneous trips.
10.2.0.2	The system shall be able to satisfy a variety of booking types, e.g. last minute, return trip, being able to take advantage of late opening hours, special facilities etc.
10.2.0.3	The system shall be able to provide access to a wide variety of destinations over a large geographic area.
10.2.0.4	The system shall be able to provide links to inter-urban and regional transport services.
10.2.0.5	The system shall provide the traveller with an easy to use user interface that minimises the amount of data to be provided by the traveller, and accepts payment in a variety of ways.
10.2.1	Information Handling
10.2.1.1	The system shall provide all the information necessary to prepare a journey.
10.2.1.2	The system shall enable the user to book a trip from a variety of access points, e.g. internet, on-street terminals, etc.
10.2.1.3	The system shall be able to predict the time that will be taken to make a particular trip.
10.2.1.4	The system shall be able to provide a service in which travellers wait a minimum period of time for a Demand Responsive PT vehicle to arrive.
10.2.1.5	The system shall be able to provide management tools suitable for the delivery of an optimum quality of service.
10.2.1.6	The system shall be able to locate and identify the Demand Responsive PT vehicles.
10.2.1.7	The system shall be able to schedule the Demand Responsive PT vehicles in real-time.
10.2.1.8	The system shall be able to plan the Demand Responsive PT vehicle trips in an optimum manner.
10.2.2	Communications
10.2.2.1	The system shall be able to provide two-way data communications between the Demand Responsive PT vehicles and a control centre.
10.2.2.2	The system shall be able to provide two-way voice communications between the Demand Responsive PT vehicles and a control centre for non-routine use.
10.2.3	Route Guidance
10.2.3.1	The system shall be able to inform the driver about the optimum route, according to specified criteria, that he or she should take for one or more trips.
10.2.4	Reporting
10.2.4.1	The system shall be able to provide statistics of usage
10.3	Shared Transport Management

10.3.0.1 The system shall permit many people, one at a time, to share the use of a single car (car pooling).

10.3.0.2 The system shall permit a (small) number of people to share the use of a car on a single journey (car sharing).

10.3.0.3 The system shall be able to register people either as a driver and/or a (paying) passenger.

10.3.0.4 The system shall enable drivers and passengers to input pooling or sharing requests from a variety of access points, using the minimum amount of data

10.3.0.5 The system shall support an interactive database of car sharers that will permit them to find suitable partners.

10.3.0.6 The system shall be able to record each trip made, both for statistical purposes and to levy a possible charge.

10.3.0.7 The system shall provide the cost of the journey to the traveller before he or she accepts the service that is being offered, unless the service is free.

10.3.0.8 The system shall support a database containing the prices being charged by drivers for carrying passengers; this shall be available to drivers and passengers before they accept the service being offered.

10.3.0.9 The system must provide a positive indication to the drivers if the service being offered is free, and what additional charges (if any) they can levy on the passengers.

10.4 On-Trip Public Transport Information

10.4.0.1 The system shall be able to inform travellers about all PT operations (including bus, rail, metro, air, taxi, car pooling etc.).

10.4.1 Information Handling

10.4.1.1 The system shall be able to provide in-vehicle general (dynamic) PT information, as well as the arrival time at, and name of, next stop for this vehicle.

10.4.1.2 The system shall be able to provide general (dynamic) PT information, personal safety information, as well as the arrival times of next vehicles, delays, etc. at mode interchanges, e.g. bus stops, in metro, railway or bus stations.

10.4.2 Traveller Interaction

10.4.2.1 The system shall provide information which is legible, understandable and capable of being assimilated very quickly by all travellers.

10.4.2.2 The system shall provide information in the native language at the output location, and/or from a user selected choice of other appropriate foreign languages, when applicable.

10.5 Public Travel Security

10.5.0.1 The system shall monitor for, and collect evidence on, illegal activities in car parks, PT facilities, PT vehicles, etc.

10.5.0.2 The system shall be able to provide two-way data and voice communication between PT vehicles and a central location.

10.5.0.3 The system shall summon assistance when drivers, or other travellers, are assaulted.

Appendix C
User Services in Japanese ITS Architecture

1.0 ADVANCES IN NAVIGATION SYSTEMS

1.1 User Service 1: Provision of Route Guidance Traffic Information. On demand, this user service provides information on traffic congestion on each route, required travel time, traffic control, operations of other transportation modes and parking space availability through navigation systems and variable message signs. The service also makes reservations for available parking. Communication for exchange of information on routes is also available among moving vehicles. The service enables drivers to choose the best travel route and transportation mode at home prior to departure or while travelling. The service is designed to improve driver convenience by rerouting traffic flow and to help drivers work out the most effective travel plan using several transportation modes.

1.1.1 Provision of route guidance information to drivers

1.1.1.1 Provide optimum route information

1.1.1.2 Provide road traffic information

1.1.1.3 Provide required travel time when congested

1.1.1.4 Guide along the selected route

1.1.1.5 Exchange information between running vehicles

1.1.2 Provision of information on other modes to drivers

1.1.2.1 Provide information on other modes operations

1.1.2.2 Provide information on parking availability

1.1.2.3 Reserve parking lot

1.1.2.4 Provide information on other transit transfers due to accidents

1.1.3 Advanced provision of route guidance information

1.1.3.1 Provide optimum route information in advance

1.1.3.2 Provide road traffic information in advance

1.1.4 Advanced provision of information on other modes

1.1.4.1 Provide information on other modes in advance

1.1.4.2 Provide information on parking availability in advance

1.1.4.3 Reserve parking lot in advance

1.2 User Service 2: Provision of Destination-related Information. On demand, this user service provides information on hotels and leisure facilities at destinations and weather information around destinations through navigation systems, information terminals and at parking and service areas along toll roads, roadway stations, home and the office. The service enables drivers to choose destinations suited to their interests prior to departure or while driving and to enjoy a more pleasant and comfortable trip.

1.2.1 Advanced provision of information on destination

1.2.1.1 Provide detailed information and reservation on destination facility and others in advance

1.2.1.2 Provide information on the facility of destination available for the disabled, the elderly and small children and others in advance

1.2.2 Provision of information on destination to drivers and others

1.2.2.1 Provide detailed information and reservation on the facility of destination and others

1.2.2.2 Provide information on the facility of destination available for the disabled, the elderly and small children and others

1.2.2.3 Provide weather information on the given area

1.2.3 Provision of information on destination at service areas, parking areas and others

1.2.3.1 Provide detailed information and reservation on the facility of destination and others at service areas, etc.

1.2.3.2 Provide information on the facility of destination available for the disabled, the elderly and small children and others at service areas, etc.

1.2.3.3 Provide weather information on the given area at service areas, etc.

2.0 ELECTRONIC TOLL COLLECTION SYSTEM

2.1 User Service 3: Electronic Toll Collection. The electronic toll collection system allows drivers to pay tolls electronically through radio communication without stopping. This will alleviate congestion at toll gates of transport-related facilities such as toll roads, parking lots and ferry terminals. Additionally, it will improve convenience for drivers through a cashless payment system, and reduce toll gate management costs.

2.1.1 Electronic toll collection on toll roads

2.1.1.1 Collect electronically on toll roads
2.1.1.2 Collect motorcycle toll electronically
2.1.1.3 Collect toll of the disabled electronically on toll road
2.1.1.4 Issue receipts in various way
2.1.2 Electronic charge of fare collection of parking lot, ferry and others
2.1.2.1 Collect parking charges electronically
2.1.2.2 Collect the charge for roadside parking electronically
2.1.2.3 Collect the fare for ferry and car-train electronically
3.0 ASSISTANCE FOR SAFE DRIVING
3.1 User Service 4: Provision of Driving and Road Conditions Information. This user service collects information on the driving environment such as road structure ahead, road surface conditions, and visibility, vehicles in surrounding areas and obstacles, and railroad crossings and signals. Through sensors installed along roadways and in vehicles, this information is transmitted to drivers of moving vehicles through on-board equipment and information terminals on a real time basis. The service is designed to help drivers get first-hand knowledge of safe and smooth driving environment. Under the service, collisions will be avoided during the daytime, and at night or in inclement weather when visibility is poor in order to ensure smooth travel environment.
3.1.1 Provision of information on road conditions
3.1.1.1 Provide weather information
3.1.1.2 Provide information on road surface condition
3.1.1.3 Provide information on road alignment
3.1.2 Provision of information on vehicles in the vicinity and others
3.1.2.1 Provide information on obstacles ahead and behind
3.1.2.2 Provide information on vehicles passing in the other lane
3.1.2.3 Provide information on intersection in city
3.1.2.4 Provide information on vehicles in the vicinity on expressway
3.1.2.5 Provide information on railroad crossing
3.1.2.6 Provide information on traffic signals and others
3.2 User Service 5: Danger Warning. Through various sensors installed on roadways and in vehicles, this user service collects information on the locations and movements of the vehicle and the vehicles in the immediate surrounding area. This service also tracks the road structure in neighbouring areas, pedestrians, obstacles, crossing vehicles, merging/diverging vehicles and pedestrians crossing streets. Through sensors mounted on vehicles, it gathers information on the drivers' unusual driving behaviour, malfunctions of engines and brakes, and the condition of the tires. The service gives a warning when conditions are considered dangerous and helps drivers make effective decisions in operating their vehicles. The service is thus designed to prevent collisions and accidents which will occur when vehicles deviate from their traffic lanes and it is designed to ensure smooth driving environment.
3.2.1 Danger warning of vehicles ahead and others
3.2.1.1 Warn of danger due to road alignment and others
3.2.1.2 Warn of danger due to vehicles ahead and following
3.2.1.3 Warn of danger due to obstacles or pedestrians
3.2.2 Danger warning of vehicles in neighbouring area and others
3.2.2.1 Warn of danger due to changing lanes
3.2.2.2 Warn of vehicles lane departure
3.2.3 Danger warning of vehicles crossing ahead and others
3.2.3.1 Warn of danger at intersection
3.2.3.2 Warn of danger at merging or demerging section
3.2.4 Danger warning of condition of drivers or vehicles
3.2.4.1 Warn a driver of danger
3.2.4.2 Warn vehicles in the vicinity of danger
3.3 User Service 6: Assistance for Driving. This user service comprises the user service of danger warning in the previous section and automatic control of vehicles. The service provides automatic control of steering and throttle in order to assist drivers in operation of their vehicles when conditions are considered dangerous, the speed slows down or the distance between vehicles is considered inadequate on expressway. It also activates when drivers suddenly fall ill or doze at the wheel. The service is designed

to prevent collisions and accidents which will occur when vehicles deviate from their traffic lanes, and to ensure a smooth driving environment.

3.3.1 Assistance for driving against danger due to vehicles ahead and others
3.3.1.1 Assist driving against danger due to road alignment and others
3.3.1.2 Assist driving against danger due to vehicles ahead and following
3.3.1.3 Assist driving against danger due to obstacles or pedestrians
3.3.1.4 Assist driving to maintain space with a leading vehicle and to maintain specified speed
3.3.1.5 Assist vehicles stop when emergency vehicle stop is required
3.3.2 Assistance for driving against danger due to vehicles in neighbouring area and others
3.3.2.1 Assist driving when changing lanes
3.3.2.2 Assist driving when departing lanes
3.3.3 Assistance for driving against danger due to vehicles crossing ahead and others
3.3.3.1 Assist driving at intersection
3.3.3.2 Assist driving when merging or demerging
3.3.4 Assistance for driving against in driver's unusual situations
3.3.4.1 Assist driving against in driver's unusual situations

3.4 User Service 7: Automated Cruise. This user service is designed to lessen the workload of drivers and reduce or possibly eliminate potential accident causes, contributing to a long-term goal of creating a nearly accident-free driving environment. The service is also intended to increase efficiency in road management operations, including snow removal and road cleaning. To achieve these objectives, driving assistance functions are developed to provide automatic control of the brake, accelerator, and steering wheel in accordance with driving environment in surrounding areas. As a result, the system keeps the vehicle at a safe speed and within a proper distance from other vehicles, and leaves the optimum driving track, bringing about a safe, smooth and automated cruise operating environment of ordinary vehicles and vehicles for management.

3.4.1 Automated cruise of general vehicles
3.4.1.1 Cruise automatically in dedicated lane
3.4.1.2 Cruise automatically when congested
3.4.1.3 Cruise automatically through a long tunnel
3.4.1.4 Cruise automatically in harsh weather
3.4.1.5 Park automatically in parking lot
3.4.2 Automated cruise of service vehicles
3.4.2.1 Cruise service vehicles automatically
3.4.2.2 Cruise snowplough automatically

4.0 OPTIMIZATION OF TRAFFIC MANAGEMENT

4.1 User Service 8: Optimization of Traffic Flow. The purpose of this user service is to improve traffic safety, create smooth traffic flow, raise amenities, enhance environment, and prevent traffic congestion or resolve it early when it occurs. Toward this end, the service provides an optimal signal control and traffic management not only in areas troubled with the deteriorating traffic congestion and environment, but also in trunk road local areas. The service also provides drivers with route guidance and a dynamic lane control through on-board equipment and information terminals. The service also supports traffic management operations, including responses to disasters.

4.1.1 Assistance for traffic management planning
4.1.1.1 Assist traffic management planning for wide-area
4.1.1.2 Assist traffic management planning for local area
4.1.1.3 Assist decision-making process on traffic management
4.1.1.4 Collect and provide basic information on traffic demand management
4.1.2 Assistance for traffic management and traffic control facility work
4.1.2.1 Analyse and evaluate traffic regulation plans
4.1.2.2 Assist operation and maintenance of traffic control facility
4.1.2.3 Assist design and installation of traffic control facility
4.1.2.4 Assist advancement for road usage approval operation
4.1.3 Assistance for parking policy
4.1.3.1 Guidance to parking lots
4.1.3.2 Conduct traffic control suitable for residential zone
4.1.3.3 Assist efficiency for illegal parking policy

4.1.3.4 Assist parking control plan
4.1.3.5 Control traffic to maintain environment along roads
4.1.4 Advancement of driver assistance
4.1.4.1 Advanced driver assistance
4.1.4.2 Assist in planning and recording of vehicles operations
4.1.5 Assistance for police activities
4.1.5.1 Discover and retrieve the theft vehicles
4.1.5.2 Improve management of police vehicles
4.1.5.3 Assist police activities
4.1.6 Maintenance of traffic order
4.1.6.1 Improve conducting after accident procedure
4.1.6.2 Advanced analysis of accident results
4.1.6.3 Make operational recording automatically
4.1.6.4 Detect, warn and prevent dangerous driving control
4.1.7 Optimization of traffic signal control
4.1.7.1 Control traffic signal at an intersection
4.1.7.2 Control traffic signal at arterial roads
4.1.7.3 Control wide-area traffic
4.1.7.4 Control traffic signals at railroad crossing
4.1.7.5 Control corresponding to a lane
4.1.8 Route guidance
4.1.8.1 Guide a route corresponding to the needs to traffic management
4.1.8.2 Guide to a lane corresponding to a vehicle type
4.1.9 Dynamic lane control
4.1.9.1 Reversible lane control
4.1.9.2 Control bus lane dynamically
4.1.9.3 Control bicycle lane dynamically
4.1.9.4 Control lanes allowed for parking
4.1.9.5 Control one-way driving dynamically
4.2 User Service 9: Provision of Traffic Restriction Information on Incident Management. This user service provides information on traffic accidents and boosts efficiency in traffic operations in order to handle traffic accidents quickly, carry out traffic control related to the accident promptly, and recover smooth traffic flow. The service also uses advanced technologies, including driving recorders, for the analysis of accidents with a view to studying more effective measures against traffic accidents.
4.2.1 Assistance for traffic management under unusual conditions
4.2.1.1 Manage traffic when disaster occurs
4.2.1.2 Manage traffic to cope with an accident
4.2.1.3 Manage traffic under unusual weather
4.2.1.4 Manage traffic under unusual traffic conditions
5.0 INCREASING EFFICIENCY IN ROAD MANAGEMENT
5.1 User Service 10: Improvement of Maintenance Operations. This user service collects data on traffic volume, conditions of road facilities, roadside environment and the location of vehicles for maintenance. At the same time, the service combines this data with data on local traffic conditions, repair of road facilities and reconstruction of urban facilities. This is fed a database in order to maintain a safe, smooth and pleasant driving environment and enforce optimum traffic restriction and then lift it at the appropriate time for advanced and efficient road management. The service also gathers information on rain, snow, fog, waves that crest over coastal roads, landslides, damage to roadways and necessary machines and materials, and the location of vehicles for rehabilitation in order to maintain a safe road environment at a time of disasters or inclement weather.
5.1.1 Assistance for road management works
5.1.1.1 Assist traffic survey
5.1.1.2 Assist road maintenance inspection
5.1.1.3 Assist environmental maintenance along road
5.1.1.4 Provide information on road maintenance
5.1.2 Improvement of road management works
5.1.2.1 Collect information on road surface

5.1.2.2 Assist service vehicles operations
5.1.3 Optimization of implementing traffic restrictions
5.1.3.1 Collect information on unusual weather and disaster
5.1.3.2 Assist decision-making on implementing traffic restrictions
5.1.3.3 Assist decision-making on lifting of traffic restrictions
5.1.4 Improvement of efficiency in disaster restoration
5.1.4.1 Assist collecting information when disaster occurs
5.1.4.2 Assist vehicles allocation for disaster restoration
5.1.4.3 Provide road traffic information when restoring

5.2 User Service 11: Management of Special Permitted Commercial Vehicles. The service provides electronic processing of both applications for passage permits of special vehicles and related paperwork, conversion of information on routes for requested passage into a database and detection of an actual passage route chosen by permitted vehicles, and the automatic vehicle weigh-in-motion. The service is designed for smooth and adequate procedures for obtaining permits for special vehicles and the monitoring of routes of vehicles for transportation of dangerous objects. Consequently, the service ensures protection of the road structure, prevention of traffic hazards, improvement of user services and reduction in operation costs.

5.2.1 Management of special permitted commercial vehicles and others
5.2.1.1 Improve approval of works for specially permitted commercial vehicle
5.2.1.2 Provide route information available for vehicles operations
5.2.1.3 Monitor overloaded vehicles operations
5.2.2 Collecting information on dangerous-load vehicle operation
5.2.2.1 Collect information on dangerous-load vehicle operation

5.3 User Service 12: Provision of Roadway Hazard Information. This user service provides drivers and carriers with information on sections subject to traffic control, the contents of traffic control, possibility of lifting control, and detours. This is done in order to ensure safe and smooth traffic in accordance with natural conditions in each region.

5.3.1 Provision of roadway hazard information
5.3.1.1 Provide information on traffic restrictions and lift
5.3.1.2 Provide information on bypass

6.0 SUPPORT FOR PUBLIC TRANSPORT

6.1 User Service 13: Provision of Public Transport Information. This user service is designed to assist public transport passengers in selecting travel modes satisfying their needs and departure time with a view to greater user convenience and optimum share of use of public transport modes. Toward this end, the service provides information on operations of public transportation and vacancies, and alternative transportation modes through information terminals installed at home or the office prior to departure, through on-board equipment of moving vehicles for public transport and portable terminals, and through information terminals installed at bus stops, taxi stands and service areas. Also available under the service is appointment for demand-response public transport, including taxis and demand buses.

6.1.1 Provision of information on public transport operation or other transit transfer
6.1.1.1 Provide information on public transport in advance
6.1.1.2 Provide information on public transport en route
6.1.1.3 Provide information on other modes operations while on board of a public transport
6.1.1.4 Provide information on delay or accidents of public transport
6.1.2 Assistance for using bus on demand, taxi and others
6.1.2.1 Assistance for bus use on demand
6.1.2.2 Assistance for taxi use

6.2 User Service 14: Assistance for Public Transport Operations and Operations Management. This user service collects real-time information on operations of public transport and provides public transport operators with the information as basic data in order to assist public transport organizations in working out operation plans and managing operations. The service also operates a public transport priority system, if deemed necessary, in connection with signal control to help boost efficiency in public transport management. The service ensures improvement of user convenience through safe and smooth operations of public transport.

6.2.1 Implementation of priority passing for public transport
6.2.1.1 Provide signal priority to bus and tram

6.2.1.2 Monitor operations on dedicated lanes such as for bus
6.2.2 Provision of public transport operations and others
6.2.2.1 Provide road traffic information and others
6.2.2.2 Provide information on public transport operations
6.2.2.3 Provide information on emergency occurrence on transit
6.2.2.4 Provide information on expressway bus users
7.0 INCREASING EFFICIENCY IN COMMERCIAL VEHICLE OPERATIONS
7.1 User Service 15: Assistance for Commercial Vehicle Operations. This user service collects real-time information on operations of commercial vehicles and road traffic, as well as information on cargoes handled by commercial vehicles, and provides transport operators with the information, if necessary, in order to support commercial vehicle operations management, pick-ups, deliveries and transshipment. The service also gathers information on operations of international container ships, ferries and railways, and provides the information with carriers, if necessary. The service is designed to increase transport efficiency, reduce the volume of commercial traffic and improve transport safety, thereby making overall freight transport efficient.
7.1.1 Provision of information on commercial vehicles operations and others
7.1.1.1 Provide commercial vehicles with road traffic information and others
7.1.1.2 Provide information on commercial vehicles operations
7.1.1.3 Provide information on commercial vehicles emergency when occurs
7.1.2 Provision of freight information
7.1.2.1 Provide freight information
7.1.3 Provision of operation information on other modes
7.1.3.1 Provide information on other modes operation
7.2 User Service 16: Automated Platooning of Commercial Vehicles. This user service enables several commercial vehicles equipped with automated cruising functions to cruise within proper distances between the vehicles for dramatic improvement in transport efficiency, reduction in the traffic volume of commercial vehicles and greater transport safety.
7.2.1 Automated platooning of commercial vehicles
7.2.1.1 Implement platooning of truck
7.2.1.2 Implement platooning of truck on the dedicated lane
8.0 SUPPORT FOR PEDESTRIANS
8.1 User Service 17: Pedestrian Route Guidance. This user service improves convenience for travel and creates a safe and pleasant roadside environment for pedestrians and cyclists, particularly the elderly and the disabled who are at increased risk to meet with traffic accidents. Toward this end, the service provides information on the current position and the location of facilities and destinations as well as route guidance through portable terminal units. The service directs pedestrians to destinations using portable terminals, magnets and acoustic guidance.
8.1.1 Provision of information on pedestrian facilities, route and others
8.1.1.1 Provide information on pedestrian self-location and facility location
8.1.1.2 Provide information on pedestrian route along the given destination
8.1.1.3 Provide information on pedestrian refuge places
8.1.2 Pedestrian route guidance
8.1.2.1 Guide pedestrian along to the given destination
8.1.2.2 Guide the visually disabled to avoid dangerous sections
8.1.2.3 Guide for wheelchair users
8.2 User Service 18: Vehicle-Pedestrian Accident Avoidance. This user service senses the existence of pedestrians within intersections and, if necessary, prolongs the walk signal duration for pedestrians. When a pedestrian meets with an accident or falls ill, or other emergencies occur, an emergency message is transmitted to homes and related organizations automatically or manually through the portable terminal. When a pedestrian is detected in the path of a vehicle and a collision is considered imminent, the service alerts the driver to the danger of a collision, or automatically applies the brake in order to prevent traffic accidents involving pedestrians and to ensure their safety. This user service creates a safe and pleasant roadside environment for pedestrians and cyclists, particularly the elderly and the disabled who are at increased risk of traffic accidents.
8.2.1 Ensuring pedestrian safety by traffic signal control

8.2.1.1 Extend green time and provide information on pedestrian waiting time to next green light and color of traffic light
8.2.2 Ensuring safety of pedestrian and others in cooperation with vehicles
8.2.2.1 Warn pedestrians of approaching vehicles and others
8.2.2.2 Restrict speed of vehicles concerning pedestrians
8.2.2.3 Provide pedestrian with information on approaching train at railroad crossing
8.2.3.4 ensure safety passing of the wheelchair users
8.2.3 Provision of information on location of pedestrian and others
8.2.3.1 Provide pedestrian emergency notification automatically
8.2.3.2 Provide information on current location of the elderly and others automatically
9.0 SUPPORT FOR EMERGENCY VEHICLE OPERATIONS
9.1 User Service 19: Automatic Emergency Notification. Under this service, a vehicle automatically or manually transmits a distress signal to related dispatch centers and emergency stations when it meets with a disaster or an accident, or a driver is in a dangerous situation. This drastically reduces the time required to identify a disaster or an accident and its location. The service is designed to carry out quick and appropriate first-aid activities and road repair.
9.1.1 Emergency notification
9.1.1.1 Notify of disasters and accidents
9.1.1.2 Notify vehicles in the vicinity of accidents
9.2 User Service 20: Route Guidance for Emergency Vehicles and Support for Relief Activities. When a disaster or an accident takes place, this user service collects real-time information on traffic conditions and damage to roads, transmits the information to related organizations, and provides support for operations and driving to direct emergency vehicles to the location of a disaster or an accident quickly.
9.2.1 Guidance for emergency vehicles and support activities
9.2.1.1 Guide emergency vehicles along the optimum route
9.2.1.2 Control traffic signals to guide emergency vehicles, giving priority
9.2.1.3 Inform vehicles of an emergency vehicles approaching
9.2.1.4 Manage emergency vehicles operations
9.2.1.5 Assist vehicles for restoration and relief works at disaster
10.0 21st USER SERVICE: INFORMATION UTILIZATION
10.1 21st User Service: Information Utilization. In developing System Architecture, the 21st user service has been defined anew in order to ensure interoperability and interconnectability with the advanced information and telecommunications society. The Comprehensive Plan for ITS in Japan has specified 20 user services. To enhance business efficiency and convenience for ITS users, this user service ensures interoperability and interconnectability regarding infrastructure, receiving/transmission terminals and information contents in areas that should be harmonized with ITS in the advanced information and telecommunications society. Specifically available on demand through navigation systems and information terminals is information to be distributed in the advanced information and telecommunications society, such as service information on travel and tourism as well as business information. The service also connects ITS with information systems in the advanced information and telecommunications society in terms of functions for the purpose of wide use of a unified toll payment system, smooth connection with road facilities and support for efficient logistics through EDI (Electronic Data Interchange).
10.1.1 Utilization of the information in the advanced information and telecommunication society
10.1.1.1 Utilize information on shopping and amenities en route
10.1.1.2 Utilize information on travel, sight sports and recreations en route
10.1.1.3 Utilize business information through mass-media en route
10.1.1.4 Utilize administration information en route
10.1.1.5 Utilize information on facility along the route when travelling
10.1.1.6 Access to the network information when travelling
10.1.1.7 Utilize banking service information on board
10.1.1.8 Utilize information on the sight-spot guidance for pedestrians
10.1.2 Utilization of information related to multi-modal transport
10.1.2.1 Warn train of danger due to rail crossing
10.1.2.2 Reserve on public transportation and use check-in service en route
10.1.2.3 Reserve public transportation at home or office and use ticket issue service

10.1.2.4 Reserve public transportation and use check-in service
10.1.2.5 Utilize public transportation with cashless payment
10.1.3 Coordination of ITS functions with advanced information and telecommunications society
10.1.3.1 Utilize all-purpose transaction method including for toll roads
10.1.3.2 Coordinate with the functions provided by facility along the routes
10.1.3.3 Utilize information on emergency relief activity
10.1.3.4 Assist for efficient logistics by EDI

Appendix D
User Services in Canadian ITS Architecture

1 TRAVELLER INFORMATION SERVICES

1.1 TRAVELLER INFORMATION

The Traveller Information user service provides travellers with information prior to their departure to assist them in making mode choices, travel time estimates, and route decisions. The sub-services of the Traveller Information user service address four major functions, which are: (1) Available Services Information, (2) Current Situation Information, (3) Trip Planning Service, and (4) User Access. Information is integrated from various transportation modes and other information sources and is presented to the user for decision making.

1.1.1 Broadcast Traveller Information

1.1.2 Interactive Traveller Information

1.1.3 Real-Time Ridesharing Information

1.2 ROUTE GUIDANCE AND NAVIGATION

The Route Guidance user service provides travellers with instructions on turns and other manoeuvres to reach selected destinations. In a simple form, a user would input a destination and be provided with a fixed recommended route. In a more dynamic mode, the user would receive instructions on course selection as the driver travelled to the destination. This could include information that takes into account traffic conditions.

1.2.1 Autonomous Route Guidance

1.2.2 Dynamic Route Guidance

1.2.3 ISP-Based Route Guidance

1.2.4 Traffic Estimation and Prediction

1.2.5 In-Vehicle Signing

1.3 RIDE MATCHING AND RESERVATION

The Ride Matching and Reservation user service expands the market for carpools and vanpools by providing real-time ride-matching information along with reservations and vehicle assignments. The sub-services of Ride Matching and Reservation provide the following functionality: (1) Rider Request, (2) Transportation Provider Services, and (3) Information Processing. This will also include a billing service to the providers.

1.3.1 Ride Matching

1.3.2 Real-Time Ride Matching

1.4 TRAVELLER SERVICES AND RESERVATIONS

The Traveller Services Information user service provides the traveller with access to yellow pages type information regarding a variety of travel-related services and facilities. The information will be accessible to the traveller in the home or office to support pre-trip planning and while enroute, either in the vehicle or at public facilities such as public transit terminals or highway rest stops.

1.4.1 Traveller Yellow Pages

1.4.2 Services Purchases and Reservations

1.4.3 Parking Facility Management

1.4.4 Regional Parking Management

2 TRAFFIC MANAGEMENT SERVICES

2.1 TRAFFIC CONTROL

The Traffic Control user service manages the movement of traffic on streets and highways. It includes surface street controls such as traffic signal systems, adaptive traffic control systems and freeway control techniques such as ramp metering and lane control. Between the eight sub-services of the Traffic Control user services, the following four functions are provided which are (1) Traffic Flow Optimisation, (2) Traffic Surveillance, (3) Control Function, and (4) Provide Information.

2.1.1 Traffic Network Flow Monitoring

2.1.2 Surface Street Control

2.1.3 Highway Control

2.1.4 Regional Traffic Control

2.1.5 Traffic Information Dissemination

2.1.6 Virtual TMC

2.1.7 Probe-Based Flow Monitoring
2.1.8 Traffic Estimation and Prediction

2.2 INCIDENT MANAGEMENT

The Incident Management user service enhances existing capabilities to identify incidents, formulate response actions, and support initiation and ongoing co-ordination of those response actions. The single sub-service of the Incident Management user service provides six major functions such as: (1) Scheduled Planned Incidents, (2) Identify Incidents, (3) Formulate Response Actions, (4) Support Co-ordinated Implementation of Response Actions, (5) Support Initialisation of Response to Actions, and (6) Predict Hazardous Conditions.

2.2.1 Incident Management Co-ordination
2.2.2 Incident Prediction System

2.3 TRAVEL DEMAND MANAGEMENT

Travel Demand Management (TDM) user service will generate data and communicate management and control strategies that will support and facilitate the implementation of TDM programs, policies and regulations. The data would include, for example, travel times, vehicle occupancy, parking availability, and vehicle pollution levels. The sub-services of the Travel Demand management user service address two major functions which are: (1) Increase Efficiency of Transportation System and (2) Provide Wide Variety of Mobility Options.

2.3.1 High Occupancy Vehicle Lane Management
2.3.2 Reversible Lane Management
2.3.3 Predictive Demand Management

2.4 ENVIRONMENTAL CONDITIONS MANAGEMENT

The Environmental Conditions and Monitoring user service will provide government agencies with the capability to enhance their air quality control strategies. The function will provide both wide area and roadside emissions monitoring as well as Road Weather Systems and Services. Information will be used by Traffic Demand Management in the Traffic Management Centre to mitigate pollution and may be provided to enforcement agencies to compel offenders to comply with standards. In addition, road weather information and forecasts will provide inputs to other systems such as ATMS and ATIS to increase safety and efficiency.

2.4.1 Roadway Environmental Sensing
2.4.2 Emissions Management
2.4.3 Road Weather Information System
2.4.4 Vehicle-Based Sensing

2.5 OPERATIONS AND MAINTENANCE

The Operations and Maintenance user service will provide government agencies, as well as contractors with the resources to manage the operations and maintenance of vehicle fleet and equipment assets, and monitor and manage traffic flow around work zone areas.

2.5.1 Infrastructure Maintenance Management
2.5.2 Smart Work Zones

2.6 AUTOMATED DYNAMIC WARNING AND ENFORCEMENT

The Automated Dynamic Warning and Enforcement user service will provide systems which warn vehicles or motorists of imminent danger, and provide electronic enforcement of traffic control and regulations.

2.6.1 Dynamic Roadway Warning
2.6.2 Variable Speed Limit and Enforcement
2.6.3 Signal Enforcement

2.7 NON-VEHICULAR ROAD USER SAFETY

The Non-Vehicular Road User Safety user service will provide warning systems primarily focused on pedestrian and bicyclist safety. These would include, for example, pedestrian crossing lights, audible pedestrian signals, and traffic signal control of bicycle routes.

2.7.1 Mixed Use Warning Systems
2.7.2 Automated Non-Vehicular Road User Protection

2.8 MULTI-MODAL JUNCTION SAFETY AND CONTROL

The Multi-Modal Junction Safety and Control user service manages traffic at at-grade highway-rail intersections. The management functions can include warning systems, barrier systems, and co-ordination between railway operations and traffic management centres.

2.8.1 Basic At-Grade Crossing Control

2.8.2 Advanced At-Grade Crossing
2.8.3 Modal Operations Co-ordination
3 PUBLIC TRANSPORT SERVICES
3.1 PUBLIC TRANSPORT MANAGEMENT

The Public Transport Management user service applies advanced vehicle electronic systems to various public transportation modes and uses the data generated by these modes to improve service to the public. It includes operation of vehicles and facilities, planning and scheduling, and personnel management.

3.1.1 Transit Vehicle Tracking
3.1.2 Transit Fixed-Route Operations
3.1.3 Passenger and Fare Management
3.1.4 Transit Maintenance
3.1.5 Multi-Modal Co-ordination
3.1.6 Multi-Modal Connection Protection
3.2 EN-ROUTE TRANSIT INFORMATION

The En-Route Transit Information user service provides travellers with real-time transit and high-occupancy vehicle information allowing travel alternatives to be chosen once the traveller is en-route. The single sub-service of the En-Route Transit information user service provides three major functions which are (1) Information Receipt, (2) Information Processing, and (3) Information Distribution. This capability integrates information from different transit modes and presents it to travellers for decision making.

3.2.1 En-Route Transit Information
3.3 DEMAND RESPONSIVE TRANSIT

The Demand Responsive Transit user service involves the use of flexibly routed transit vehicles offering more convenient service to customers. These transit vehicles include small buses, taxicabs, or fixed-route transit buses that are detoured from their pre-established route to pickup or discharge passengers.

3.3.1 Demand Responsive Transit
3.4 PUBLIC TRAVEL SECURITY

The Public Travel Security user service supports innovative applications of technology to improve the security of public transportation. Security concerns include protecting transit patrons and employees from street crime, maintaining an environment of actual and perceived security, and developing innovative technical measures to respond to incidents.

3.4.1 Public Travel Security
4 ELECTRONIC PAYMENT SERVICES
ELECTRONIC PAYMENT SERVICES
4.1 The Electronic Payment Services user service allows travellers to pay for transportation services by electronic means. Between the four sub-services of the Electronic Payment user services provided the following functionality, which are: (1) Electronic Toll Collection, (2) Electronic Fare Collection, (3) Electronic Parking Payment, and (4) Electronic Payment Services Integration. It may, as envisioned, also serve broad non-transportation functions and may be integrated with credit and debit cards in banking and other financial transactions.

4.1.1 Electronic Toll Collection
4.1.2 Electronic Parking Payment
4.1.3 Transit Services Payment
4.1.4 Traveller Services Payment
5 COMMERCIAL VEHICLE OPERATIONS
5.1 COMMERCIAL VEHICLE ELECTRONIC CLEARANCE

The Commercial Vehicle Electronic Clearance user service consists of both domestic and international border electronic clearances. Domestic electronic clearance will allow commercial vehicles to continue past inspection stations without stopping. International border clearance will allow vehicles to bypass international border checkpoints without stopping, or at least with expedited checks. As a vehicle approaches an inspection station or checkpoint, vehicle to roadside communications take place that identify the vehicle and make available to authorities the necessary data about credentials, vehicle weight, safety status, cargo, and occupants. Enforcement personnel can then select potentially unsafe vehicles for inspection and allow safe and legal vehicles to bypass the inspection station/checkpoint.

5.1.1 Electronic Clearance
5.1.2 International Border Crossing Clearance
5.1.3 Weigh-In-Motion (WIM)

5.2 AUTOMATED ROADSIDE SAFETY INSPECTION

The Automated Roadside Safety Inspection user service will provide automated inspection capabilities that check safety requirements more quickly and accurately during a safety inspection that is performed when a vehicle has been pulled off the highway at a fixed or mobile inspection site. An example would be a rolling dynamometer which checks brake performance.

5.2.1 Inspection Support Systems

5.2.2 Automated Vehicle Safety Read Out

5.3 ON-BOARD SAFETY MONITORING

The On-board Safety Monitoring user service will provide for the ability to sense the safety status of a vehicle, cargo, and the driver at mainline speeds. Driving time and driver alertness are the conditions sensed for the driver. Warnings or indications of the safety status are provided to the driver. This data would also be provided to the carrier, and to enforcement authorities. Of primary importance is to inform the driver, as soon as possible, of any problem that has been detected. Of secondary importance is notifying the carrier of detected safety problems. Last in importance is the notification of appropriate enforcement agencies.

5.3.1 On-Board Safety Monitoring

5.4 COMMERCIAL VEHICLE ADMINISTRATIVE PROCESSES

The Commercial Vehicle Administrative Process user service includes: 1) electronic purchase of credentials, 2) automated mileage and fuel reporting and auditing, and 3) international border electronic clearance.

5.4.1 Commercial Vehicle Administrative Processes

5.5 INTERMODAL FREIGHT MANAGEMENT

The Intermodal Freight Management user service will provide systems which will monitor the status of freight in-transit, and at freight terminals.

5.5.1 Freight In-Transit Monitoring

5.5.2 Intermodal Interface Management

5.6 COMMERCIAL FLEET MANAGEMENT

The Commercial Fleet Management user service provides real-time communications for vehicle location, dispatching and tracking between commercial vehicle drivers, dispatchers, and intermodal transportation providers, thereby reducing delays for drivers and providing commercial drivers and dispatchers with real-time routing information in response to congestion or incidents. Commercial fleet management includes the management of taxi fleets.

5.6.1 Fleet Administration

5.6.2 Freight Administration

5.6.3 CVO Fleet Maintenance

6 EMERGENCY MANAGEMENT SERVICES

6.1 EMERGENCY NOTIFICATION AND PERSONAL SECURITY

The Emergency Notification And Personal Security user service provides the capability for the user to manually initiate a distress signal for incidents like mechanical breakdown or non-injury collisions. An automated system would help mitigate the consequences of a serious collision by automatically sending information regarding the location, nature and severity of the collision to an emergency services dispatcher and/or to hospital and emergency room personnel.

6.1.1 Personal Security

6.1.2 MAYDAY Support

6.2 HAZARDOUS MATERIAL PLANNING AND INCIDENT RESPONSE

The Hazardous Materials (HAZMAT) Incident Response user service

6.2.1 Hazardous Material Planning Incident Response

6.3 DISASTER RESPONSE AND MANAGEMENT

The Disaster Response and Management user service will co-ordinate disaster response strategies from a virtual control centre, and disseminate information to agencies and individuals on traffic conditions, diversion routes etc.

6.3.1 Disaster Command and Control

6.3.2 Disaster Information Dissemination

6.4 EMERGENCY VEHICLE MANAGEMENT

The Emergency Vehicle Management Service user service is oriented towards reducing the time from the receipt of notification of an incident by an emergency services dispatcher, and the arrival of emergency

vehicles on the scene. It includes emergency vehicle fleet management, route guidance to the incident scene or a suitable hospital, and

6.4.1 Emergency Response Management

6.4.2 Emergency Vehicle Routing

7 VEHICLE SAFETY AND CONTROL SYSTEMS

7.1 VEHICLE-BASED COLLISION AVOIDANCE

The Vehicle-based Crash Avoidance user service consists of systems which improve the driver s ability to avoid or decrease the severity of longitudinal or lateral collisions. These types of collisions can potentially be avoided by providing warnings and/or assuming temporary control of the vehicle if a collision is imminent.

7.1.1 Lateral Warning Systems

7.1.2 Lateral Collision Avoidance

7.1.3 Longitudinal Warning Systems

7.1.4 Longitudinal Collision Avoidance

7.2 INFRASTRUCTURE-BASED COLLISION AVOIDANCE

The Infrastructure-based Crash Avoidance user service improves the driver s ability to avoid or decrease the severity of crashes that occur at intersections or merge areas. The function of this service is to track the position and state of vehicles within a defined area surrounding

7.2.1 Intersection Collision Warning

7.2.2 Intersection Collision Avoidance

7.3 SENSOR-BASED DRIVING SAFETY ENHANCEMENT

The Sensor-based Driving Safety Enhancement user service will reduce the number and severity of collisions in which impaired or reduced senses is a factor (primarily visual). For example, systems that provide this service will improve visually acquired information in situations where driving visibility is low, such as night or foggy conditions.

7.3.1 Sensor-based Driving Safety Enhancement

7.4 SAFETY READINESS

The Safety Readiness user service will reduce the number and severity of collisions caused by impaired drivers, vehicle component failures, or degraded infrastructure conditions. The impaired driver warning and control override systems would monitor various driver performance features for indications that the driver may not be in a condition to continue operating the vehicle safely. The vehicle condition warning systems would monitor the performance of components, such as tires and brakes. The in-vehicle infrastructure condition warning systems would detect and warn the driver of unsafe conditions such as the presence of ice or water on the roadway.

7.4.1 Vehicle Safety Monitoring

7.4.2 Driver Safety Monitoring

7.5 PRE-COLLISION RESTRAINT DEPLOYMENT

The Pre-Collision Restraint Deployment user service reduces the number and severity of injuries by providing a means to anticipate an imminent collision and to activate passenger safety systems prior to actual impact.

7.5.1 Pre-Collision Restraint Deployment

7.6 AUTOMATED VEHICLE OPERATION

The Automated Vehicle Operation user service is a vehicle-roadway system that will improve the safety and efficiency of highway travel, enhance driver comfort, and help reduce air pollution by moving suitably equipped vehicles with under fully automated control (hands-off and feet-off operation) along dedicated highway lanes.

7.6.1 Automated Vehicle Operation

8 INFORMATION WAREHOUSING SERVICES

8.1 WEATHER AND ENVIRONMENTAL DATA MANAGEMENT

The Weather and Environmental Data Management user service provides system wide gathering, fusion, and dissemination of information on roadway weather conditions and forecasts.

8.1.1 Roadway and Weather Data Fusion

8.1.2 Environmental Information Dissemination

8.1.3 Roadway Meso and Micro Prediction

8.2 ARCHIVED DATA MANAGEMENT

The Archived Data Management user service provides a data warehouse of historical transportation data. The sub-services of the Archived Data Management user service provide the functionality to warehouse data as well as co-ordinate the distribution of the data to users.

8.2.1 Archived Data Mart
8.2.2 Archived Data Warehouse
8.2.3 Archived Data Virtual Warehouse

Transit Vehicle Tracking (apts1)

This market package provides for an Automated Vehicle Location System to track the transit vehicle's real time schedule adherence and updates the transit system's schedule in real-time. Vehicle position may be determined either by the vehicle (e.g., through GPS) and relayed to the infrastructure or may be determined directly by the communications infrastructure. A two-way wireless communication link with the Transit Management Subsystem is used for relaying vehicle position and control measures. Fixed route transit systems may also employ beacons along the route to enable position determination and facilitate communications with each vehicle at fixed intervals. The Transit Management Subsystem processes this information, updates the transit schedule and makes real-time schedule information available to the Information Service Provider Subsystem via a wireline link.

Transit Fixed-Route Operations (apts2)

This market package performs automatic driver assignment and monitoring, as well as vehicle routing and scheduling for fixed-route services. This service uses the existing AVL database as a source for current schedule performance data, and is implemented through data processing and information display at the transit management subsystem. This data is exchanged using the existing wireline link to the information service provider where it is integrated with that from other transportation modes (e.g. rail, ferry, air) to provide the public with integrated and personalized dynamic schedules

Demand Response Transit Operations (apts3)

This market package performs automatic driver assignment and monitoring as well as vehicle routing and scheduling for demand response transit services. This package uses the existing AVL database to monitor current status of the transit fleet and supports allocation of these fleet resources to service incoming requests for transit service while also considering traffic conditions. The Transit Management Subsystem provides the necessary data processing and information display to assist the transit operator in making optimal use of the transit fleet. The Information Service Provider Subsystem may be either be operated by transit management center or be independently owned and operated by a separate service provider. In the first scenario, the traveler makes a direct request to a specific paratransit service. In the second scenario, a third party service provider determines the paratransit service is a viable means of satisfying a traveler request and uses wireline communications to make a reservation for the traveler.

Transit Passenger and Fare Management (apts4)

This market package allows for the management of passenger loading and fare payments on-board vehicles using electronic means. The payment instrument may be either a stored value or credit card. This package is implemented with sensors mounted on the vehicle to permit the driver and central operations to determine vehicle loads, and readers located either in the infrastructure or on-board the transit vehicle to allow fare payment. Data is processed, stored, and displayed on the transit vehicle and communicated as needed to the Transit Management Subsystem using existing wireless infrastructure.

Transit Security (apts5)

This market package provides for the physical security of transit passengers. An on-board security system is deployed to perform surveillance and warn of potentially hazardous situations. Public areas (e.g. stops, park and ride lots, stations) are also monitored. Information is communicated to the Transit Management Subsystem using the existing or emerging wireless (vehicle to center) or wireline (area to center) infrastructure. Security related information is also transmitted to the Emergency Management Subsystem when an emergency is identified that requires an external response. Incident information is communicated to the Information Service Provider.

Transit Maintenance (apts6)

This market package supports automatic maintenance scheduling and monitoring. On-board condition sensors monitor critical system status and transmit critical status information to the Transit Management Subsystem. Hardware and software in the Transit Management Subsystem processes this data and schedules maintenance activities.

Multi-modal Coordination (apts7)

This market package establishes two way communications between multiple transit and traffic agencies to improve service coordination. Intermodal coordination between transit agencies can increase traveler convenience at transfer points and also improve operating efficiency. Coordination between traffic and transit management is intended to improve on-time performance of the transit system to the extent that this can be accommodated without degrading overall performance of the traffic network. More limited local coordination between the transit vehicle and the individual intersection for signal priority is also supported by this package.

Transit Traveler Information (apts8)

This market package provides transit users at transit stops and on-board transit vehicles with ready access to transit information. The information services include transit stop annunciation, imminent arrival signs, and real-time transit schedule displays that are of general interest to transit users. Systems that provide custom transit trip itineraries and other tailored transit information services are also represented by this market package.

Broadcast Traveler Information (atis1)

This market package provides the user with a basic set of ATIS services; its objective is early acceptance. It involves the collection of traffic conditions, advisories, general public transportation and parking information and the near real time dissemination of this information over a wide area through existing infrastructures and low cost user equipment (e.g., FM subcarrier, cellular data broadcast). Different from the market package ATMS6--Traffic Information Dissemination--which provides the more basic HAR and DMS information capabilities, ATIS1 provides the more sophisticated digital broadcast service. Successful deployment of this market package relies on availability of real-time transportation data from roadway instrumentation, probe vehicles or other means.

Interactive Traveler Information (atis2)

This market package provides tailored information in response to a traveler request. Both real-time interactive request/ response systems and information systems that "push" a tailored stream of information to the traveler based on a submitted profile are supported. The traveler can obtain current information regarding traffic conditions, transit services, traveler services, ride share/ride match, parking management, and pricing information. A range of two-way wide-area wireless and wireline communications systems may be used to support the required digital communications between traveler and the information service provider. A variety of interactive devices may be used by the traveler to access information prior to a trip or en-route to include phone, kiosk, Personal Digital Assistant, personal computer, and a variety of in-vehicle devices. Successful deployment of this market package relies on availability of real-time transportation data from roadway instrumentation, probe vehicles or other means.

Autonomous Route Guidance (atis3)

This market package relies on in-vehicle sensory, location determination, computational, map database, and interactive driver interface equipment to enable route planning and detailed route guidance based on static, stored information. No communication with the infrastructure is assumed or required. Identical capabilities are available to the traveler outside the vehicle by integrating a similar suite of equipment into portable devices.

Dynamic Route Guidance (atis4)

This market package offers the user advanced route planning and guidance which is responsive to current conditions. The package combines the autonomous route guidance user equipment with a digital receiver capable of receiving real-time traffic, transit, and road condition information which is considered by the user equipment in provision of route guidance.

ISP Based Route Guidance (atis5)

This market package offers the user advanced route planning and guidance which is responsive to current conditions. Different than the Dynamic Route Guidance Market Package, this market package moves the route planning function from the user device to the information service provider. This approach simplifies the user equipment requirements and can provide the infrastructure better information on which to predict future traffic and appropriate control strategies to support basic route planning with minimal user equipment. The package includes two way data communications and optionally also equips the vehicle with the databases, location determination capability, and display technology to support turn by turn route guidance.

Integrated Transportation Management/Route Guidance (atis6)

This market package allows a traffic management center to continuously optimize the traffic control strategy based on near-real time information on intended routes for a proportion of the vehicles within their network while offering the user advanced route planning and guidance which is responsive to current conditions. It would utilize the individual and ISP route planning information to optimize signal timing while at the same time providing updated signal timing information to allow optimized route plans. The use of predictive link times for this market package are possible through utilizing the market package ATMS9--Traffic Prediction and Demand Management--at the traffic management center.

Yellow Pages and Reservation (atis7)

This market package enhances the Interactive Traveler Information package by adding infrastructure provided yellow pages and reservation capabilities to tailored requests for information regarding traffic conditions, transit services, traveler services, ride share/ride match, parking management, and pricing information. The same basic user equipment is included; service or advertising fees should allow recovery of the ISP investment. This market package provides multiple ways for accessing information either while en-route in a vehicle using wide-area wireless communications or pre-trip via wireline connections.

Dynamic Ridesharing (atis8)

This market package enhances the Interactive Traveler Information package by adding infrastructure provided dynamic ridesharing capability to tailored requests for information regarding traffic conditions, transit services, traveler services, ride share/ride match, parking management, and pricing information. If this service is provided by a private ISP, service fees may be required to allow for recovery of the ISP investment. In terms of equipment requirements, ATIS8 is similar to ATIS7.

In Vehicle Signing (atis9)

This market package supports distribution of traffic and travel advisory information to drivers through in-vehicle devices. It includes short range communications between roadside equipment and the vehicle and wireline connections to the Traffic Management Subsystem for coordination and control. This market package also informs the driver of both highway-highway and highway-rail intersection status.

Network Surveillance (atms01)

This market package includes traffic detectors, environmental sensors, other surveillance equipment, the supporting field equipment, and wireline communications to transmit the collected data back to the Traffic Management Subsystem. The derived data can be used locally such as when traffic detectors are connected directly to a signal control system or remotely (e.g., when a CCTV system sends data back to the Traffic Management Subsystem). The data generated by this market package enables traffic managers to monitor traffic and road conditions, identify and verify incidents, detect faults in indicator operations, and collect census data for traffic strategy development and long range planning. The collected data can also be analyzed and made available to users and the Information Service Provider Subsystem.

Probe Surveillance (atms02)

This market package provides an alternative approach for surveillance of the roadway network. Two general implementation paths are supported by this market package: 1) wide-area wireless communications between the vehicle and Information Service Provider is used to communicate current vehicle location and status, and 2) dedicated short range communications between the vehicle and roadside is used to provide equivalent information back to the Traffic Management Subsystem. The first approach leverages wide area communications equipment that may already be in the vehicle to support personal safety and advanced traveler information services. The second approach utilizes vehicle equipment that supports toll collection, in-vehicle signing, and other short range communications applications identified within the architecture. The market package enables traffic managers to monitor road conditions, identify incidents, analyze and reduce the collected data, and make it available to users and private information providers. It requires one of the communications options identified above, roadside beacons and wireline communications for the short range communications option, data reduction software, and utilizes wireline links between the Traffic Management Subsystem and Information Service Provider Subsystem to share the collected information. Both "Opt out" and "Opt in" strategies are available to ensure the user has the ability to turn off the probe functions to ensure individual privacy. Due to the large volume of data collected by probes, data

reduction techniques are required in this market package which include the ability to identify and filter out-of-bounds or extreme data reports.

Surface Street Control (atms03)

This market package provides the central control and monitoring equipment, communication links, and the signal control equipment that support local surface street control and/or arterial traffic management. A range of traffic signal control systems are represented by this market package ranging from static pre-timed control systems to fully traffic responsive systems that dynamically adjust control plans and strategies based on current traffic conditions and priority requests. Additionally, general advisory and traffic control information can be provided to the driver while en-route. This market package is generally an intra-jurisdictional package that does not rely on real-time communications between separate control systems to achieve area-wide traffic signal coordination. Systems that achieve coordination across jurisdictions by using a common time base or other strategies that do not require real time coordination would be represented by this package. This market package is consistent with typical urban traffic signal control systems.

Freeway Control (atms04)

This market package provides the communications and roadside equipment to support ramp control, lane controls, and interchange control for freeways. Coordination and integration of ramp meters are included as part of this market package. This package is consistent with typical urban traffic freeway control systems. This package incorporates the instrumentation included in the Network Surveillance Market Package to support freeway monitoring and adaptive strategies as an option. This market package also includes the capability to utilize surveillance information for detection of incidents. Typically, the processing would be performed at a traffic management center; however, developments might allow for point detection with roadway equipment. For example, a CCTV might include the capability to detect an incident based upon image changes. Additionally, this market package allows general advisory and traffic control information to be provided to the driver while en-route.

HOV Lane Management (atms05)

This market package manages HOV lanes by coordinating freeway ramp meters and connector signals with HOV lane usage signals. Preferential treatment is given to HOV lanes using special bypasses, reserved lanes, and exclusive rights-of-way that may vary by time of day. Vehicle occupancy detectors may be installed to verify HOV compliance and to notify enforcement agencies of violations.

Traffic Information Dissemination (atms06)

This market package allows traffic information to be disseminated to drivers and vehicles using roadway equipment such as dynamic message signs or highway advisory radio. This package provides a tool that can be used to notify drivers of incidents; careful placement of the roadway equipment provides the information at points in the network where the drivers have recourse and can tailor their routes to account for the new information. This package also covers the equipment and interfaces that provide traffic information from a traffic management center to the media (for instance via a direct tie-in between a traffic management center and radio or television station computer systems), transit management center, emergency management center, and information service provider.

Regional Traffic Control (atms07)

This market package advances the Surface Street Control and Freeway Control Market Packages by adding the communications links and integrated control strategies that enable integrated interjurisdictional traffic control. This market package provides for the sharing of traffic information and control among traffic management centers to support a regional control strategy. The nature of optimization and extent of information and control sharing is determined through working arrangements between jurisdictions. This package relies principally on roadside instrumentation supported by the Surface Street Control and Freeway Control Market Packages and adds hardware, software, and wireline communications capabilities to implement traffic management strategies which are coordinated between allied traffic management centers. Several levels of coordination are supported from sharing of information through sharing of control between traffic management centers.

Incident Management System (atms08)

This market package manages both predicted and unexpected incidents so that the impact to the transportation network and traveler safety is minimized. Requisite incident detection capabilities are included in the freeway control

market package and through the regional coordination with other traffic management and emergency management centers, weather service entities, and event promoters supported by this market package. Information from these diverse sources are collected and correlated by this market package to detect and verify incidents and implement an appropriate response. This market package provides Traffic Management Subsystem equipment that supports traffic operations personnel in developing an appropriate response in coordination with emergency management and other incident response personnel to confirmed incidents. The response may include traffic control strategy modifications and presentation of information to affected travelers using the Traffic Information Dissemination market package. The same equipment assists the operator by monitoring incident status as the response unfolds. The coordination with emergency management might be through a CAD system or through other communication with emergency field personnel. The coordination can also extend to tow trucks and other field service personnel.

Traffic Prediction and Demand Management (atms09)

This market package includes advanced algorithms, processing, and mass storage capabilities that support historical evaluation, real-time assessment, and forecast of the roadway network performance. This includes the prediction of travel demand patterns to support better link travel time forecasts. The source data would come from the Traffic Management Subsystem itself as well as other traffic management centers and predicted traffic loads derived from route plans supplied by the Information Service Provider Subsystem. In addition to short term forecasts, this market package provides longer range forecasts that can be used in transportation planning. This market package provides data that supports the implementation of TDM programs, and policies managing both traffic and the environment. Information on vehicle pollution levels, parking availability, usage levels, and vehicle occupancy are collected by monitoring sensors to support these functions. Demand management requests can also be made to Toll Administration, Transit Management, and Parking Management Subsystems.

Electronic Toll Collection (atms10)

This market package provides toll operators with the ability to collect tolls electronically and detect and process violators. Variations in the fees that are collected enables implementation of demand management strategies. Dedicated short range communication between the roadway equipment and the vehicle is required as well as wireline interfaces between the toll collection equipment and transportation authorities and the financial infrastructure that supports fee collection. Vehicle tags of toll violators are read and electronically posted to vehicle owners. Standards, inter-agency coordination, and financial clearinghouse capabilities enable regional, and ultimately national interoperability for these services. The population of toll tags and roadside readers that these systems utilize can also be used to collect road use statistics for highway authorities. This data can be collected as a natural by-product of the toll collection process or collected by separate readers that are dedicated to probe data collection.

Emissions Monitoring and Management (atms11)

This market package monitors individual vehicle emissions and provides general air quality monitoring using distributed sensors to collect the data. The collected information is transmitted to the emissions management subsystem for processing. Both individual detection and identification of vehicles that exceed emissions standards and general area-wide monitoring of air quality are supported by this market package. For area wide monitoring, this market package measures air quality, identifies sectors that are non-compliant with air quality standards, and collects, stores and reports supporting statistical data. For point emissions monitoring, this market package measures tail pipe emissions and identifies vehicles that exceed emissions standards. The gathered information can be used to implement environmentally sensitive TDM programs, policies, and regulations.

Virtual TMC and Smart Probe Data (atms12)

This market package provides for special requirements of rural road systems. Instead of a central TMC, the traffic management is distributed over a very wide area (e.g., a whole state or collection of states). Each locality has the capability of accessing available information for assessment of road conditions. The package uses vehicles as smart probes that are capable of measuring road conditions and providing this information to the roadway for relay to the Traffic Management Subsystem and potentially direct relay to following vehicles (i.e., the automated road signing equipment is capable of autonomous operation). In-vehicle signing is used to inform drivers of detected road conditions.

Standard Railroad Grade Crossing (atms13)

This market package manages highway traffic at highway-rail intersections (HRIs) where operational requirements

do not dictate more advanced features (e.g., where rail operational speeds are less than 80 miles per hour). Both passive (e.g., the crossbuck sign) and active warning systems (e.g., flashing lights and gates) are supported. (Note that passive systems exercise only the single interface between the roadway subsystem and the driver in the architecture definition.) These traditional HRI warning systems may also be augmented with other standard traffic management devices. The warning systems are activated on notification by interfaced wayside equipment of an approaching train. The equipment at the HRI may also be interconnected with adjacent signalized intersections so that local control can be adapted to highway-rail intersection activities. Health monitoring of the HRI equipment and interfaces is performed; detected abnormalities are reported to both highway and railroad officials through wayside interfaces and interfaces to the traffic management subsystem. Similar interfaces and services are provided for other types of multimodal crossings (e.g., draw bridges).

Advanced Railroad Grade Crossing (atms14)

This market package manages highway traffic at highway-rail intersections (HRIs) where operational requirements demand advanced features (e.g., where rail operational speeds are greater than 80 miles per hour). This market package includes all capabilities from the Standard Railroad Grade Crossing Market Package and augments these with additional safety features to mitigate the risks associated with higher rail speeds. The active warning systems supported by this market package include positive barrier systems which preclude entrance into the intersection when the barriers are activated. Like the Standard Package, the HRI equipment is activated on notification by wayside interface equipment which detects, or communicates with the approaching train. In this market package, additional information about the arriving train is also provided by the wayside interface equipment so that the train's direction of travel, its estimated time of arrival, and the estimated duration of closure may be derived. This enhanced information may be conveyed to the driver prior to, or in context with, warning system activation. This market package also includes additional detection capabilities which enable it to detect an entrapped or otherwise immobilized vehicle within the HRI and provide an immediate notification to highway and railroad officials.

Railroad Operations Coordination (atms15)

This market package provides an additional level of strategic coordination between rail operations and traffic management centers. Rail operations provides train schedules, maintenance schedules, and any other forecast events which will result in highway-rail intersection (HRI) closures. This information is used to develop forecast HRI closure times and durations which may be used in advanced traffic control strategies or to enhance the quality of traveler information.

Parking Facility Management (atms16)

This market package provides enhanced monitoring and management of a parking facility. The included equipment assists in the management of parking operations, coordinates with transportation authorities, and supports electronic collection of parking fees. This is performed by sensing and collecting current parking facility status, sharing the data with information service providers and traffic operations, and automatic fee collection using short range communications with the same in-vehicle equipment utilized for electronic toll collection.

Reversible Lane Management (atms17)

This market package provides for the management of reversible lane facilities. In addition to standard surveillance capabilities, this market package includes sensory functions that detect wrong-way vehicles and other special surveillance capabilities that mitigate safety hazards associated with reversible lanes. The package includes the field equipment, physical lane access controls, and associated control electronics that manage and control these special lanes. This market package also includes the equipment used to electronically reconfigure intersections and manage right-of-way to address dynamic demand changes and special events.

Road Weather Information System (atms18)

This market package monitors current and forecast road and weather conditions using a combination of weather service information and data collected from environmental sensors deployed on and about the roadway. The collected road weather information is monitored and analyzed to detect and forecast environmental hazards such as icy road conditions, dense fog, and approaching severe weather fronts. This information can be used to more effectively deploy road maintenance resources, issue general traveler advisories, and support location specific warnings to drivers using the Traffic Information Dissemination Market Package.

Vehicle Safety Monitoring (avss01)

This market package will diagnose critical components of the vehicle and warn the driver of potential dangers. On-board sensors will determine the vehicle's condition and performance, determine on-board safety data and display information.

Driver Safety Monitoring (avss02)

This market package will determine the driver's condition, and warn the driver of potential dangers. On-board sensors will determine the driver's condition and performance, determine on-board safety data and display information.

Longitudinal Safety Warning (avss03)

This market package allows for longitudinal warning. It utilizes safety sensors and collision sensors. It requires on-board sensors to monitor the areas in front of and behind the vehicle and present warnings to the driver about potential hazards.

Lateral Safety Warning (avss04)

This market package allows for lateral warning. It utilizes safety sensors and collision sensors. It requires on-board sensors to monitor the areas to the sides of the vehicle and present warnings to the driver about potential hazards.

Intersection Safety Warning (avss05)

This market package will determine the probability of a collision in an equipped intersection (either highway-highway or highway-rail) and provide timely warnings to drivers in response to hazardous conditions. Monitors in the roadway infrastructure assess vehicle locations and speeds near an intersection. Using this information, a warning is determined and communicated to the approaching vehicle using a short range communications system. Information can be provided to the driver through the market package ATIS9--In-Vehicle Signing.

Pre-Crash Restraint Deployment (avss06)

This market package provides in-vehicle sensors to monitor the vehicle's local environment, determine collision probability and deploy a pre-crash safety system. It will include on-board sensors to measure lateral and longitudinal gaps and together with weather and roadway conditions will determine lateral and longitudinal collision probability. It will have the mechanism to deploy a pre-crash safety system.

Driver Visibility Improvement (avss07)

This market package will enhance driver visibility using an enhanced vision system. On-board display hardware is needed.

Advanced Vehicle Longitudinal Control (avss08)

This market package automates the speed and headway control functions on board the vehicle. It utilizes safety sensors and collision sensors combined with vehicle dynamics processing to control the throttle and brakes. It requires on-board sensors to measure longitudinal gaps and a processor for controlling the vehicle speed.

Advanced Vehicle Lateral Control (avss09)

This market package automates the steering control on board the vehicle. It utilizes safety sensors and collision sensors combined with vehicle dynamics processing to control the steering. It requires on-board sensors to measure lane position and lateral deviations and a processor for controlling the vehicle steering.

Intersection Collision Avoidance (avss10)

This market package will determine the probability of an intersection collision and provide timely warnings to approaching vehicles so that avoidance actions can be taken. This market package builds on the Intersection Collision Warning infrastructure and in-vehicle equipment and adds equipment in the vehicle that can take control of the vehicle in emergency situations. The same monitors in the roadway infrastructure are needed to assess vehicle locations and speeds near an intersection. This information is determined and communicated to the approaching vehicle using a short range communications system. The vehicle uses this information to develop control actions which alter the vehicle's speed and steering control and potentially activate its pre-crash safety system.

Automated Highway System (avss11)

This market package enables "hands-off" operation of the vehicle on the automated portion of the highway system. Implementation requires lateral lane holding, vehicle speed and steering control, and Automated Highway System check-in and checkout. This market package currently supports a balance in intelligence allocation between infrastructure and the vehicle pending selection of a single operational concept by the AHS consortium.

Fleet Administration (cvo01)

This market package keeps track of vehicle location, itineraries, and fuel usage at the Fleet and Freight Management Subsystem using a cell based or satellite data link and the pre-existing wireless infrastructure. The vehicle has a processor to interface to its sensor (e.g., fuel gauge) and to the cellular data link. The Fleet and Freight Management Subsystem can provide the vehicle with dispatch instructions, and can process and respond to requests for assistance and general information from the vehicle via the cellular data link. The market package also provides the Fleet Manager with connectivity to intermodal transportation providers using the existing wireline infrastructure.

Freight Administration (cvo02)

This market package tracks cargo and the cargo condition. This information is communicated with the Fleet and Freight Management Subsystem via the existing wireless infrastructure. Interconnections are provided to intermodal shippers and intermodal freight depots for tracking the cargo from source to destination.

Electronic Clearance (cvo03)

This market package provides for automated clearance at roadside check facilities. The roadside check facility communicates with the Commercial Vehicle Administration subsystem over wireline to retrieve infrastructure snapshots of critical carrier, vehicle, and driver data to be used to sort passing vehicles. This package allows a good driver/vehicle/ carrier to pass roadside facilities at highway speeds using transponders and dedicated short range communications to the roadside. The roadside check facility may be equipped with AVI, weighing sensors. transponder read/write devices, computer workstation processing hardware, software, and databases.

CV Administrative Processes (cvo04)

This market package provides for electronic application, processing, fee collection, issuance, and distribution of CVO credential and tax filing. Through this process, carriers, drivers, and vehicles may be enrolled in the electronic clearance program provided by a separate market package which allows commercial vehicles to be screened at mainline speeds at commercial vehicle check points. Through this enrollment process, current profile databases are maintained in the Commercial Vehicle Administration Subsystem and snapshots of this database are made available to the commercial vehicle check facilities at the roadside to support the electronic clearance process.

International Border Electronic Clearance (cvo05)

This market package provides for automated clearance specific to international border crossings. This package augments the electronic clearance package by allowing interface with customs related functions and permitting NAFTA required entry and exit from the US to Canada and Mexico.

Weigh-In-Motion (cvo06)

This market package provides for high speed weigh-in-motion with or without AVI attachment. Primarily this market package provides the roadside with additional equipment, either fixed or removable. If the equipment is fixed, then it is thought to be an addition to the electronic clearance and would work in conjunction with the AVI and AVC equipment in place.

Roadside CVO Safety (cvo07)

This market package provides for automated roadside safety monitoring and reporting. It automates commercial vehicle safety inspections at the Commercial Vehicle Check roadside element. The capabilities for performing the safety inspection are shared between this market package and the On-Board CVO Safety Market Package which enables a variety of implementation options. The basic option, directly supported by this market package, facilitates safety inspection of vehicles that have been pulled in, perhaps as a result of the automated screening process provided by the Electronic Clearance Market Package. In this scenario, only basic identification data and status information is read from the electronic tag on the commercial vehicle. The identification data from the tag enables access to additional safety data maintained in the infrastructure which is used to support the safety inspection, and

may also inform the pull-in decision if system timing requirements can be met. More advanced implementations, supported by the On-Board CVO Safety market package, utilize additional vehicle safety monitoring and reporting capabilities in the commercial vehicle to augment the roadside safety check.

On-board CVO Safety (cvo08)

This market package provides for on-board commercial vehicle safety monitoring and reporting. It is an enhancement of the Roadside CVO Safety Market Package and includes roadside support for reading on-board safety data via tags. This market package uses the same communication links as the Roadside CVO Safety Market Package, and provides the commercial vehicle with a wireless link (data and possibly voice) to the Fleet and Freight Management and the Emergency Management Subsystems. Safety warnings are provided to the driver as a priority with secondary requirements to notify the Fleet and Freight Management and Commercial Vehicle Check roadside elements.

CVO Fleet Maintenance (cvo09)

This market package supports maintenance of CVO fleet vehicles through close interface with on-board monitoring equipment and AVLS capabilities within the Fleet and Freight Management Subsystem. Records of vehicle mileage, repairs, and safety violations are maintained to assure safe vehicles on the highway.

HAZMAT Management (cvo10)

This market package integrates incident management capabilities with commercial vehicle tracking to assure effective treatment of HAZMAT material and incidents. HAZMAT tracking is performed by the Fleet and Freight Management Subsystem. The Emergency Management subsystem is notified by the Commercial Vehicle if an incident occurs and coordinates the response. The response is tailored based on information that is provided as part of the original incident notification or derived from supplemental information provided by the Fleet and Freight Management Subsystem. The latter information can be provided prior to the beginning of the trip or gathered following the incident depending on the selected policy and implementation.

Emergency Response (em1)

This market package provides the computer-aided dispatch systems, emergency vehicle equipment, and wireless communications that enable safe and rapid deployment of appropriate resources to an emergency. Coordination between Emergency Management Subsystems supports emergency notification and coordinated response between agencies. Existing wide area wireless communications would be utilized between the Emergency Management Subsystem and an Emergency Vehicle to enable an incident command system to be established and supported at the emergency location. The Emergency Management Subsystem would include hardware and software for tracking the emergency vehicles. Public safety, traffic management, and many other allied agencies may each participate in the coordinated response managed by this package.

Emergency Routing (em2)

This market package supports dynamic routing of emergency vehicles and coordination with the Traffic Management Subsystem for special priority on the selected route(s). The Information Service Provider Subsystem supports routing for the emergency fleet based on real-time traffic conditions and the emergency routes assigned to other responding vehicles. In this market package, the Information Service Provider Subsystem would typically be integrated with the Emergency Management Subsystem in a public safety communications center. The Emergency Vehicle would also optionally be equipped with dedicated short range communications for local signal preemption.

Mayday Support (em3)

This package allows the user (driver or non-driver) to initiate a request for emergency assistance and enables the Emergency Management Subsystem to locate the user and determine the appropriate response. The Emergency Management Subsystem may be operated by the public sector or by a private sector provider. The request from the traveler needing assistance may be manually initiated or automated and linked to vehicle sensors. The data is sent to the Emergency Management subsystem using wide area wireless communications with voice as an option. Providing user location implies either a location technology within the user device or location determination within the communications infrastructure.

ITS Planning (its1)

This market package supports ITS planning functions. It accepts data from every center subsystem and uses this data to plan new deployments. This data also supports policy decision making, allocation of funding, allocation of resources and other planning activities.